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PROCESSING OF COMBINED DOMESTIC BATH
AND LAUNDRY WASTE WATERS FOR REUSE
AS COMMODE FLUSHING WATER

*Warren D. Hypes, Carmen E. Batten,
and Judd R. Wilkins*

*Langley Research Center
Hampton, Va. 23665*



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16. Abstract <p>An experimental investigation of processes and system configurations for reclaiming combined bath and laundry waste waters for reuse as commode flush water has been conducted. A 90-min recycle flow was effective in removing particulates and in improving other physical characteristics to the extent that the filtered water was subjectively acceptable for reuse. The addition of a charcoal filter resulted in noticeable improvements in color, turbidity, and suds elimination. Heating and chlorination of the waste waters were investigated for reducing total organism counts and eliminating coliform organisms. A temperature of 335.9 K (145° F) for 30 min and chlorine concentrations of 20 mg/l in the collection tank followed by 10 mg/l in the storage tank were determined to be adequate for this purpose. Water volume relationships and energy-use rates for the waste water reuse systems are also discussed.</p>					
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PROCESSING OF COMBINED
DOMESTIC BATH AND LAUNDRY WASTE WATERS
FOR REUSE AS COMMODE FLUSHING WATER

Warren D. Hypes, Carmen E. Batten, and Judd R. Wilkins
Langley Research Center

SUMMARY

An experimental investigation of processes and system configurations for reclaiming combined bath and laundry waste waters for reuse as commode flush water has been conducted. Filtration by single-pass, 90-min recycle, and 120-min recycle flows through a diatomaceous earth cake filter has been investigated as a means for improving chemical/physical characteristics of waste waters. A 90-min recycle flow was effective in removing particulates down to $1\text{ }\mu\text{m}$ in maximum dimension and in improving other physical characteristics to the extent that the filtered water was subjectively acceptable for reuse. Adsorption during single-pass and 90-min recycle flows through activated charcoal following filtration by diatomaceous earth was investigated as a further improvement in physical characteristics and selected chemical characteristics. A 90-min recycle flow was more effective and resulted in noticeable reductions in color, turbidity, and sudsing.

Heating of the waste waters to temperatures of 330.4 K (135°F) and 335.9 K (145°F) for periods of 15, 30, and 45 min and chlorination at available chlorine concentrations of 1, 15, 20, and 25 mg/l to reduce total organism counts and eliminate coliform organisms were investigated. A temperature of 335.9 K (145°F) for 30-min and chlorine concentrations of 20 mg/l in the collection tank followed by 10 mg/l in the storage tank were determined to be adequate for this purpose.

The energy-use rate for the reclamation system using diatomaceous earth filtration and chlorine sterilization was 0.695 kWh/day.

INTRODUCTION

The Langley Research Center is conducting an experimental program to explore the feasibility of applying life support system technology to domestic water and waste management problems. The planned experimental program will investigate several water conservation and reuse concepts. One concept that appears attractive is the reuse of bath and laundry waste waters for commode flushing water. Application of this concept can reduce household water requirements up to 40 percent (ref. 1) while possibly requiring minimum treatment of the waste waters. The selection of treatment techniques, however, is made difficult because of the absence of specific water quality standards for commode flush water. At the present

time, the only water quality standards applicable to waters used in a domestic living unit are drinking water standards published by the Public Health Service (ref. 2). In the absence of suitable standards to be used as processing goals, processes and hardware units were tested by comparing their relative ability to improve the chemical/physical and microbiological qualities of waste waters.

The test program was conducted in two parts. In the first part, reclamation processes were evaluated and the results were used to select candidates for further evaluation as components of complete systems. The evaluation of complete reuse systems in a simulated typical household was conducted in the second part. This report documents both parts of the test program.

TEST SETUP AND INSTRUMENTATION

The test setup shown in figure 1 included a wood platform divided into a kitchen, laundry, and bathroom; an area beneath the platform for collecting and processing waste waters; and a walkway behind the platform for access to the plumbing lines and water meters. The kitchen, laundry, and bathroom contained commercially available household appliances and fixtures. In addition, a commercially available hot water tank was located on the lower level. The lower level simulated a household basement or an apartment furnace and utility room. Domestic water, sewerage, and power services were provided to the setup through connections with the building services. Hot and cold water flow to all appliances and fixtures was measured to the nearest 0.4 l (0.1 gal) by conventional rotary-disc water meters. Each meter was calibrated in place at the temperature and line pressure encountered during use. Meter errors ranged between 0 and 6.0 percent. All water volumes discussed in this report have been corrected on the basis of the meter calibrations. Electric power required by system components was continuously monitored and recorded with strip chart wattmeters.

TESTS AND RESULTS

PROCESS TESTS

Previous experimental studies conducted to characterize typical domestic bath and laundry waste waters established the need for improving the chemical/physical and biological quality of the waters before reuse (ref. 3). Processes selected for improving water quality must also retain practical features of low cost and operational simplicity. On the basis of these criteria, diatomaceous earth filtration was selected as a candidate for improving physical qualities of the waste waters, and heat and chlorination were selected as candidates for improving biological qualities.

Prior to incorporating one or more of these processes into an experimental water reuse system, it was necessary to determine the ability of the process to improve water quality and to determine the most practical operational procedures for its use. These experimental investigations are discussed in this section.

Diatomaceous Earth Filtration

Filtration by diatomaceous earth is commonly used in industrial and domestic applications for filtering suspended particulates from water. Diatomaceous earth, a white silica powder of plant skeletal origin, can be deposited on a support screen to form a thin layer. This layer, commonly referred to as a cake filter, traps particulates as water is pumped continuously under low pressure through the porous cake and support screen. When the filter cake becomes overburdened with particulates, the entire cake is backwashed off the filter screen and fresh diatomaceous earth material is deposited to form a new cake. A diatomaceous earth filter of this type was used in the test program as a treatment process to improve the chemical/physical characteristics of the bath and laundry waters for reuse. The filter unit used in the tests was a commercial unit marketed for swimming pool applications. As purchased, the unit contained 1.39 m² (15 ft²) of filter area composed of six nylon screen discs to be coated with a total of 1.02 kg (2.25 lb) of diatomaceous earth. The screen disc assembly is shown in figure 2. For typical swimming pool application, where water flow would be continuous and thus hold the diatomaceous earth on the screen discs, the discs would be oriented vertically, with the common metal center tube oriented horizontally. In the experimental setup, where water flows were intermittent, the screen discs were oriented horizontally, with the center tube oriented vertically. Thus, the screen discs presented a top and bottom surface. Subsequently, the bottom of each disc was covered with a neoprene membrane to block flow through the bottom. With one-half of the original filter area blocked, the quantity of diatomaceous earth was reduced to 0.51 kg (1.125 lb) per charge. The top surface continued to be a filtering surface whose flat orientation permitted the recirculating pump to operate intermittently without having the diatomaceous powder fall away. The operational flow pattern is shown in figure 2. A change in position of the flow control valves permitted the unit to be backwashed to the drain. The unit complete with outer housing and installed in the test setup is shown in figure 3. A schematic of the test setup used for all tests of the diatomaceous earth filter is shown in figure 4.

Procedure

Prior to the test, the washing machine, bathtub-shower tankage, and water transfer lines were rinsed with tap water chlorinated to a concentration of approximately 5 mg/l.

The assembly was then drained. It was again rinsed with tap water and drained. The collection tank was refilled with tap water to be used in the procedure for depositing diatomite powder on the screen disc assembly. The charge tank was then loaded with 3.8 l (1 gal) of tap water mixed with 0.51 kg (1.125 lb) of diatomaceous earth powder. Tap water was then pumped from the collection tank through the filter unit and into the storage tank. The flow created a suction on the charge tank withdrawing the water and diatomite powder solution, which were then mixed with the pumped flow prior to entering the diatomite filter unit. Upon reaching the filter discs, the diatomite powder was trapped on the porous surfaces of the discs. The deposition resulted in a 1.6- to 3.2-mm-thick (1/16 to 1/8 in.) layer which formed the cake filter.

Waste bath and laundry waters were collected from a bathtub-shower and an automatic washing machine. At the beginning of each of the 3 test days, four showers were taken and one load of mixed domestic laundry was washed. A single hand soap was used for all four showers on a given day but different soaps were used on each of the 3 days that constituted a specific test. A different laundry detergent was used on each test day. Selection changes in the hand soaps and laundry detergents were programmed into the test plan to produce possible changes in the chemical/physical characteristics of the wash waters. All waste waters were collected in a 416.4-l (110-gal) polypropylene collection tank. Samples for chemical/physical analyses were taken daily from the collection tank and the storage tank. The sample from the collection tank was taken immediately after the day's charge of waste water was complete, and the sample from the storage tank was taken immediately after the filtration step was completed.

The procedures just described were common to each of the four specific process tests, hereinafter referred to as tests, A, B, C, and D, accomplished with diatomaceous earth filtration. Tests A, B, and C were conducted to determine the most efficient operational mode for improving the chemical/physical characteristics of the waste waters. Individual differences in procedures used for these tests are discussed in the following paragraphs.

For test A, a single pass of waste water through the filter unit was employed. After the total load of waste water for a single day was collected in the collection tank, the waste water was pumped by a centrifugal pump through the filter unit to the storage tank. No attempt was made to control pressure and flow rate, except that a maximum discharge pressure of 276 kN/m^2 (40 psig) was established because of limitations on the pump and filter unit housing.

Test B was conducted with the flow recirculating through the filter unit for 120 min. Pumping procedures were the same as those used in test A other than the changes in valve positions required to effect the recirculating flow. At the end of the 120-min period, valve positions were changed to pump the filtered water to the storage tank.

Test C utilized a 90-min recirculating flow through the filter unit. Pumping procedures were the same as in test B.

Test D was conducted to determine the efficiency of the diatomaceous filter unit in removing the large suspended and settleable lint and grit particles that are present in bath and laundry waste waters (ref. 3). The test utilized a 90-min recirculating flow through the filter unit. Pumping procedures through deposition of the diatomaceous earth filtered water in the storage tank were the same as in test B. From the storage tank, the water was pumped through a series of white cotton fiber filters arranged as shown in figure 5. The particle removal ratings of the filters in order from inlet to outlet were 50, 25, 10, 5, and 1 μm . Pumping procedure and valve positions were controlled to maintain inlet pressure at the first filter at approximately 276 kN/m^2 (40 psig). Pressures downstream of the first filter were not controlled but were recorded. Increasing pressure drops across filters were used as indicators of particulate removal. Samples for chemical/physical analyses were not taken in test D, since the analyses would not be pertinent to the objective of the test.

Results

The combined bath and laundry waste waters were analyzed for the characteristics listed in table I. The table also lists the techniques used to measure each characteristic and the lowest concentration limit that can be detected by the water analysis laboratory. Detailed listings of the chemical/physical characteristics of the bath and laundry waste water before and after diatomaceous earth filtration for tests A, B, and C are given in tables II, III, and IV. Those characteristics having values after filtration significantly lower than the values before filtration for all three tests are as follows:

Characteristic	Test A (single pass)			Test B (120-min recycle)			Test C (90-min recycle)		
	Before filter	After filter	Percent decrease	Before filter	After filter	Percent decrease	Before filter	After filter	Percent decrease
Calcium, mg/l . . .	24	22	8	25	18	28	28	23	18
Phosphates, mg/l . .	69	51	26	38	23	40	57	47	18
Total organic carbon, mg/l . . .	159	102	36	105	24	77	53	30	43
Total solids, mg/l . .	439	353	20	372	214	42	465	351	25
Turbidity (SiO_2 equiv.), mg/l . . .	177	124	30	160	42	74	133	42	68

These values are averages of the daily values for each respective test. In addition to having lower average values after filtration, each of the listed characteristics show lower

values after filtration for each individual day. Slight decreases in color intensities resulting from filtration can be subjectively detected. (See table I, footnote c.) Values for two other characteristics, MBAS¹ and sodium, show a trend toward reduction by filtration but do not show a consistent daily reduction. Two characteristics, copper and zinc, tend to increase after filtration. The increases are believed to be caused by the release of copper ions in the system tubing and zinc ions from the electrolysis-inhibiting zinc anode built into the housing for the diatomaceous earth filter. Inspection of the averages for the three tests shows that the multipass filtration modes are more efficient than the single-pass mode in reducing the values of the characteristics.

It was assumed that the diatomaceous earth filter would remove large and settleable particulates present in the bath and laundry waste water. During each of the single-pass filtrations of test A, continued increasing filter inlet pressure and decreasing flow rate indicated that particulates were being trapped by the filter. It could not be concluded from the data, however, that single-pass filtration would result in maximum particulate removal. Visual inspection of the filtered water led to the subjective conclusion that additional filtration would remove more particulates. This conclusion prompted the investigation of the recycle operational mode of test B.

The flow-rate data for test B, the 120-min recycle mode, are plotted in figure 6. The data show a repeating daily flow rate as a function of time. The time at which the flow rate becomes constant at a pressure of 276 kN/m^2 (40 psig) was selected as the optimum recycle time. This selection is based on the assumption that the conditions of constant flow rate and pressure indicate that particulate filtration has been completed. The plot indicates that a 90-min recycle is adequate. On the basis of the results of test B, a 90-min recycle period was selected for test C. The flow-rate data for test C are also plotted in figure 6. The same relationship between flow rate and time observed in test B is seen in test C. In both tests, flow rates have become constant or near constant after a 90-min recycle period.

The results of test D demonstrate the particulate-removal ability of the diatomaceous earth filter unit. The data given in table V show that after 2339 l (618 gal) of waste laundry and bath water have been processed through diatomaceous earth, only 1 gram of particulates is removed by additional processing of the water through the wound cotton fiber filters having particle removal rating of 1 to 50 μm . But when approximately the same volume of water was processed through similar cotton fiber filters without the preceding filtration by diatomaceous earth, 298 grams of particulates were removed (ref. 4).

¹Methylene blue active substance; the test for determining the presence of a substance that reacts with methylene blue is used to indicate the presence of surfactants in soaps and detergents.

Tables VI and VII give line pressures before and after each of the wound cotton fiber filters during the tests when they were preceded by diatomaceous earth filtration and when not preceded by diatomaceous earth filtration, respectively. After diatomaceous earth filtration, the line pressures in the filter array remain relatively constant and the average daily process rates are high. When the water is processed through the wound cotton fiber filters not preceded by diatomaceous earth, the line pressures and resulting process rates drop rapidly. The drops were so severe that the cotton fiber filter cartridges were replaced after 882 l and again after 2294 l (233 and 606 gal) of water were processed (ref. 4).

Heat Sterilization

In addition to improving the chemical/physical and particulate characteristics of the bath and laundry water prior to reuse, it is necessary to reduce the total microbial population in the waste waters. Certain types of microbes, the coliforms, must be reduced to near zero ($\leq 1/100$ ml (ref. 2)), and one known effective way to kill microbes is with heat. Only the level of heat and duration of application for waste bath and laundry water needed to be determined. In order to make this determination, a 3-day test was conducted during which bath and laundry waste water filtered through diatomaceous earth was heated to 330.4 and 335.9 K (135° and 145° F) and held for periods of 15, 30, and 45 min at both temperatures.

Procedure

The Heat Sterilization Test was conducted subsequent to the test B Diatomaceous Earth Filtration Test. After reaching the storage tank where test B terminated, water to be heat sterilized was transferred by a centrifugal circulation pump to a glass-lined, electrically heated, hot water tank sized for 249.8 l (66 gal) of water. Heater elements were energized and the water temperature was raised to the predetermined level. This temperature was held for the duration of the test period, samples were taken, and the hot water tank was drained.

Baseline samples of tap water were taken from the collection tank and storage tank ports prior to the test. In addition, a baseline sample of tap water was taken from the water heater after the maximum temperature setting of 350.9 K (172° F) was reached. During the test, samples for microbial analyses were taken daily from the collection tank, storage tank, and hot water tank. The sample from the collection tank was taken immediately after the day's charge of waste water was collected, and the sample from the storage tank was taken immediately after the filtration step was completed. Samples were also taken from the hot water tank after 15-, 30-, and 45-min dwell periods at the test temperature. Longer dwell periods at elevated temperature did occur, however, since the water was heated from ambient temperature to the test temperature before the dwell period was

timed. Approximately a 1-hr period was required to raise the temperature to the lowest of the test temperatures, 330.4 K (135° F).

Samples from each of the three tanks were collected through valve-operated stainless steel sample ports. Ports were flamed before and after each sample was taken. Samples were collected in sterile containers and were processed within 30 min after collection. Total organism counts were obtained by plating appropriate dilutions on Trypticase soy agar. Coliform organism counts were obtained by plating appropriate dilutions on Endo agar. All samples were incubated for 48 hr at a temperature of 308.2 K (95° F).

Results

The total and coliform organism counts before and after heating are given in table VIII. The data show that a temperature of 330.4 K (135° F) for 15 min is effective in reducing total and coliform organism counts but that 335.9 K (145° F) for a minimum of 30 min is required to reduce coliform counts to the desired level.

The energy requirement for heat sterilization at 335.9 K (145° F) averaged 2.88 kWh for 249.8 l (66 gal) based on the 90-min heat up and 30-min dwell period at a heater power of 1.44 kW.

Chlorine Sterilization

A second known way to kill micro-organisms in water is with chlorination. Municipal drinking water is chlorinated as a routine practice, and the required chlorination levels are well established. The required chlorination levels for sterilizing waste waters such as unprocessed or filtered bath and laundry water are not well known, however, and tests were conducted to determine these levels. Several exploratory tests were conducted to establish an approximate chlorine concentration required for complete or nearly complete organism kill. These tests indicated that 1 mg/l of chlorine was not adequate and that 25 mg/l resulted in complete kill of coliforms and nearly complete kill of total organisms. Further exploratory tests indicated that 15 mg/l of chlorine was the lowest concentration that left a detectable free chlorine content of greater than 1 mg/l after a 2-hr dwell in unprocessed bath and laundry wash water. It was assumed, therefore, that 15 mg/l would be required to achieve adequate sterilization. On the basis of the exploratory tests, 15 to 25 mg/l of chlorine was selected as the concentration range to be investigated.

Procedure

The Chlorine Sterilization Test was conducted in conjunction with the Diatomaceous Earth Filter Test, test C. After collecting the daily bath and laundry waste water in the collection tank and removing samples for analyses, a chlorine solution was added to the

collection tank to raise the concentration to the desired level. The solution was prepared by mixing granular swimming-pool-type chlorine (sodium dichloro-s-triazinetriene, 100%) in distilled water to produce a solution with an available chlorine concentration of 10 000 mg/l. Specific volumes of this solution were added to the collection tank, depending on the volume of water in the tank, to raise the overall concentration to the specified level. The specified level for test day 1 was 15 mg/l. The levels for subsequent days were to be determined on the basis of results from the preceding day. After chlorination, the water was processed through the diatomaceous earth filter and deposited in the storage tank. From the storage tank, the water was transferred by a shallow well jet pump and pressure tank to a conventional commode tank. The commode was flushed 21 times each day at specific intervals to simulate a previously determined typical family living pattern (ref. 4).

Samples for microbial analyses were taken from the collection tank, storage tank, and commode water closet. Prior to the test a tap water baseline sample was taken from each of the three locations. During the 3-day test, seven samples were taken daily. One sample was taken before chlorination and one was taken after chlorination from the collection tank. One sample was taken from the storage tank after the water had been processed by diatomaceous earth filtration. Four samples were taken from the commode tank, one at 8 a.m., at 10 a.m., at 12 m., and at 3 p.m., to provide an approximation of the microbial profile of the commode tank throughout the day.

Samples from the collection tank and storage tank were taken as previously described. Those from the commode tank were withdrawn by sterile pipets from the approximate center of the water body.

Results

The total and coliform organism counts determined from the samples are given in table IX. The analyses of the tap water rinse show that the test setup was not in a sterile condition at the beginning of the test. Analyses of the water chlorinated to a concentration of 15 mg/l show that the chlorination was effective initially in reducing the coliform counts in the collection and storage tanks but that the effect was not carried to the commode tank, the sample location of maximum interest. The recontamination by coliforms occurring after the storage tank indicates that residual chlorine levels beyond the storage tank were not sufficiently high. On the basis of this observation, the chlorination concentration was increased to 20 mg/l during test days 2 and 3. The increase in chlorine concentration was adequate to eliminate coliforms for the remainder of the test. The total counts in the collection and storage tanks were reduced by the chlorination levels of 15 and 20 mg/l, but the effect was not carried to the commode water closet.

SYSTEM DEMONSTRATION TESTS

After determination of the ability of several processes to improve the chemical/physical and biological quality of bath and laundry water, tests were conducted to evaluate selected processes and components further as elements of complete water reuse systems. Three water reuse system loops were assembled and tested. Each system included at least one process step for improving the chemical/physical quality and one process step for improving the biological quality. Two systems, one using diatomaceous earth filtration and chlorine sterilization and a second using charcoal adsorption in addition to diatomaceous earth filtration and chlorine sterilization, are discussed in this report. A third system using reverse-osmosis filtration and chlorine sterilization is the subject of a separate report (ref. 4).

Diatomaceous Earth Filtration and Chlorination Sterilization

Process tests proved the ability of diatomaceous earth filtration and chlorine sterilization to improve the quality of bath and laundry waste water on a daily basis, with each day being a separate entity. These two process steps were integrated into a water reuse loop system and tested under realistic domestic conditions over a 12-day period. The 12-day period had previously been established as a period of time within which living patterns would show an effect on the chemical and microbiological characteristics of a reuse loop system and on the balance between waste water available and reuse water demand (ref. 3).

Procedure

A reuse loop system using diatomaceous earth filtration with a 90-min recycle period and chlorine sterilization was assembled as shown schematically in figure 7. A photograph of the system is presented as figure 8. Prior to the test, all tanks and lines were sterilized with tap water chlorinated to a concentration of 50 mg/l and left in the system for 2 days. The system was then twice drained and flushed with tap water. Subsequently, 189.2 l (50 gal) of tap water were added to the storage tank. A portion of this water was then used to fill the jet pump, pressure tank, commode tank, and lines between the pressure tank and commode tank. Also prior to the first day of the test, the collection tank was loaded with waste waters from one tub bath, one shower bath, and a load of laundry. Waste waters were then chlorinated to a level of 20 mg/l. Thus, at the beginning of the first day of the test, there were 172.2 l (45.5 gal) of chlorinated waste water in the collection tank, 113.6 l (30 gal) of tap water in the storage tank, and 75.7 l (20 gal) of tap water in the pressure tank, lines, and water closet.

Portions of the test plan were established to duplicate a 12-day test during which unprocessed bath and laundry waters were reused for commode flushing (ref. 3). The family patterns of bathing, laundering, and commode use were duplicated. The same single hand

soap and single laundry detergent were used. Details on the daily number of tub and shower baths, laundry loads, and commode flushes are given in table X.

During each day of the test, most of the waste water collected during the previous day was processed through the diatomaceous earth filter and transferred to the storage tank, where it mixed with processed water retained from the previous day. At the beginning of the test, it was not planned to chlorinate the water again after the collection tank. But a first-day analysis showed the chlorine concentration in the storage tank to be less than 0.05 mg/l, and it was decided to chlorinate the processed water in the storage tank to a level of 10 mg/l. Thus, all water was chlorinated once in the collection tank and again the following day in the storage tank. Once water reached the storage tank, it remained in the tank until required for commode flush. When transfer of most of the water from the collection tank to the storage tank was complete, the water remaining in the collection tank was dumped to the sewer line, and the drainage action combined with the sloped bottom of the tank allowed the particles that had settled to the bottom to be washed out. The drain valve was then closed and the next daily collection of bath and laundry water was initiated.

Samples for chemical/physical analyses were taken daily from the collection tank, storage tank, and commode tank. Those from the collection tank were taken immediately after all bath and laundry waters were collected but before daily chlorination of the collection tank. The samples were subjected to a complete analysis of the chemical/physical characteristics listed in table I. Samples from the storage tank were taken immediately after the filtration process but before daily chlorination of the storage tank. A complete analysis was accomplished on these samples. Samples from the commode tank were taken at 8 and 10 a.m., 12 m., and 3 p.m. They were analyzed for residual chlorine only.

Samples for microbiological analyses were taken from the same locations and at the same time as those for chemical/physical analyses. All microbiological samples were analyzed for total counts and coliform counts.

All samples, chemical/physical and microbiological, taken from the collection tank were from a separate batch of wash waters each day. Since the storage tank and subsequent plumbing were not drained daily, those from the storage tank and commode tank were composites. The composites included waters processed the previous day, waters processed the current day, and occasionally makeup tap water. The addition of makeup tap water was controlled by a float switch in the storage tank. When the volume of water in the tank fell below 56.8 l (15 gal), the float switch activated a solenoid valve that opened to permit the addition of tap water. When the volume of water reached approximately 75.7 l (20 gal), the float switch deactivated the solenoid valve and water flow was cut off.

Results

Chemical/physical.- A detailed daily listing of the chemical/physical characteristics of the combined bath and laundry waste water before processing is given in table XI. A listing after processing is given in table XII. Averages² of characteristics from table XI which show significant increases above baseline tap water and the corresponding average values after processing (from table XII) are presented in the following summary table:

Characteristic	Baseline tap water	Combined bath and laundry waters		
		Before process	After process	Percent reduction
Conductivity, μ mhos/cm	180	414	369	11
MBAS, mg/l	0.3	52	53	0
Odor, threshold number	0	2.2	1.6	27
Phosphates, mg/l	0.4	138	85	38
Potassium, mg/l	1.3	5.6	5.0	11
Sodium, mg/l	9	78	65	17
Sulfates, mg/l	33	60	49	18
Total organic carbon, mg/l	17	43	35	19
Total solids, mg/l	195	549	460	16
Turbidity (SiO_2 equiv.), mg/l	4	55	29	47
Urea, mg/l	1	3	4	0

The list of characteristics with high values before processing is very similar to the list obtained in the 12-day test during which unprocessed bath and laundry waste waters were reused for commode flushing (ref. 3). Of the 11 characteristics shown in the summary table to have considerably higher values in unfiltered waste waters than in tap water, 10 were higher than their tap water values in the tests of reference 3. The other characteristic, urea, was not high in the previous test; but a urea decomposition product, ammonia, was higher. The values of nine of these characteristics were reduced by diatomaceous earth filtration. In addition, the intensities of the brown and gray colors were reduced slightly by filtration. Values for calcium and pH were also reduced by filtration, although their values in unfiltered waste waters were not significantly higher than in tap water. The values for chlorine, copper, urea, and zinc showed a tendency to increase slightly during filtration. Residuals

² In computing averages, values below the lower detection limit were assumed to be at the next highest value below the limit. For example, the lower detection limit for ammonia (N) is 0.05; values below the detection limit were assumed to be 0.04. Thus, average values are approximate.

from the chlorination process are a likely source of the chlorine. The copper system plumbing lines and zinc electrode in the filter housing are believed to be the sources of the increases in copper and zinc. The urea is believed to be of human origin.

In the absence of a water quality standard for flush water, the acceptability of the processed water must be based on reasonable judgment. Subjectively the water was acceptable. The physical characteristics of color, odor, and turbidity were not objectionable, although a further reduction would be desirable. Some visible sudsing occurred upon flushing but the sudsing was not considered objectionable. The potential for suds to appear is evidenced by the relatively high values for MBAS. A reduction in the MBAS values is desirable. The potential staining agents — copper, manganese, and iron — are not problems in the concentrations detected in the unprocessed or processed waters.

Microbiological.- A detailed listing of the total and coliform microbial counts in the collection tank, storage tank, and commode tank is given in table XIII. Total counts in samples from the commode tank, the sample location of prime interest, were reduced by chlorination, but to a lesser extent than coliform counts. The total counts varied widely during each day and between days. They ranged from frequent counts of zero to equally frequent high counts of 2.61×10^6 cells/ml. Coliform counts in samples from the commode tank were reduced to zero in all but 2 of 44 samples. These two counts of 1.0×10^1 and 1.2×10^3 coliforms/100 ml were low, and subsequent respective counts returned to zero.

The data also show that the single chlorination to a level of 20 mg/l in the collection tank was not adequate to eliminate the coliforms. The second chlorination to a level of 10 mg/l in the storage tank was needed.

Water and energy use.- Water use-rate data were obtained for calculation of the relationship between waters available and waters used. These data are presented in table XIV and are summarized in the following table:

	12-day total	
	liters	gallons
Flush water required	2538.2	670.6
Combined bath and laundry waters available	3541.2	935.6
Makeup tap water	253.6	67.0
Collection tank overflow	79.9	21.1
Water withdrawn for samples	90.8	24.0
Collection tank drain	878.3	232.0

These data can be used to establish a water balance. The balance can be stated as

$$V_f = V_a + V_m - V_o - V_s - V_d - V_{te} \quad (1)$$

where

V_f flush water used

V_a waste water available

V_m makeup water added

V_o water lost in collection-tank overflow

V_s water withdrawn for samples

V_d water drained from collection tank

V_{te} water remaining in tanks at test end in excess of water in tanks at test initiation

In units of liters:

$$2538.2 \approx 3541.2 + 253.6 - 79.9 - 90.8 - 878.3 - 193.0$$

$$2538.2 \approx 2552.8$$

In units of gallons:

$$670.6 \approx 935.6 + 67.0 - 21.1 - 24.0 - 232.0 - 51.0$$

$$670.6 \approx 674.5$$

The difference of 14.6 l (3.9 gal) between the two sides of the expected balance is due to experimental error and is insignificant to the results.

When compared with data from a previous 12-day test (ref. 3) conducted with an identical number and time sequencing of baths, laundry loads, and commode flushes, these data show the effect of a shallow-trap commode on the water balance of a waste water reuse system. The previous test utilized a standard-trap commode which required 3934.7 l

(1039.5 gal) of flush water. There were 3568.6 l (942.8 gal) of combined bath and laundry water available for reuse as commode flush water. Assuming 100-percent recovery, which was not obtained because of overflow losses, makeup tap water was still required. The shallow-trap commode required 2538.2 l (670.6 gal) of flush water. There were 3541.2 l (935.6 gal) of combined bath and laundry water available for reuse as commode flush water. Thus, the volume of waste water available was greater than the volume required for flushing. Assuming 100-percent recovery, there was an excess of waste water available and no makeup water was required. However, 253.6 l (67.0 gal) of tap water were added to make up losses due to overflow and collection tank drainage. The volume of tap water added amounted to 10 percent of the volume of flush water used. It would be desirable to eliminate the overflow, but the collection tank drainage action should be retained. The drainage action combined with the conical shape of the tank bottom was effective in removing the large amount of particles settled on the tank bottom. Utilization of a shallow-trap commode should permit the design of a reuse system that would retain the periodic tank drainage procedure while reducing losses to the extent that makeup water would not be required.

Three liquid transfer pumps in the reuse loop system were the components that used electrical energy. The diatomaceous earth filter pump operated at 410 W at the filter operating pressure of 276 kN/m^2 (40 psig). Since the filtration period was 90 min, the energy-use rate was 0.615 kWh/day. The shallow-well jet pump used for tank pressurization operated at 1 kW at the tank pressure setting of 138 kN/m^2 (20 psig) to 276 kN/m^2 (40 psig). The pump operated once per flush for an average time of 12 sec per flush. With 21 flushes per day, the energy-use rate was 0.07 kWh/day. The chlorinator pump operated an average of 12 min per day at 50 W. The energy used was 0.01 kWh/day. The total energy-use rate, therefore, was 0.695 kWh/day.

Diatomaceous Earth Filtration With Charcoal Adsorption and Chlorine Sterilization

The results of the 12-day Diatomaceous Earth Filtration and Chlorine Sterilization Test proved that the combination was effective in improving the quality of the waste waters. Although the treated water was judged to be adequate for toilet flushing, several values of chemical/physical characteristics remained at levels higher than desirable. Specifically, the value of MBAS remained at a level sufficient to cause suds to form during flushing. A commercial charcoal water treatment filter was added to the reuse loop system to reduce the MBAS level. In addition, it was anticipated that the charcoal filter would further reduce the values of other selected organic and physical characteristics that remained high after diatomaceous earth filtration.

Procedure

A reuse loop system using diatomaceous earth filtration with charcoal adsorption and chlorine sterilization was assembled as shown schematically in figure 9. For the first 6 days of testing, the charcoal filter was located in the diatomaceous earth recycle loop, as shown in figure 9. During the 90-min recycle period, the water continuously circulated through the collection tank, diatomaceous earth filter, and charcoal filter. After the 90-min period, the water was directed to the storage tank. During the last 6 days of testing, the charcoal filter was located between the pressure tank and the commode tank. (This filter arrangement is not shown in fig. 9.) In this configuration, single-pass adsorption occurred as water moved through the charcoal filter in batches corresponding in volume and time to the commode flushing sequence.

During both 6-day test periods, the charcoal filter was charged with 0.028 m^3 (1 ft^3) of a commercially available water-treating charcoal which was rinsed twice with distilled water and drained before being placed in the canister. The entire charcoal charge was replaced between the two 6-day periods.

After assembly, the reuse loop system was cleaned and preloaded with tap water as discussed for the 12-day Diatomaceous Earth Filtration and Chlorine Sterilization Test. The procedures for bathing, washing clothes, flushing the commode, and collecting samples were identical with those of the previous test. The procedures for dumping the small residual volume of water from the bottom of the collection tank each day to remove accumulated particles and of allowing makeup tap water to enter the storage tank when needed were also repeated. Chlorination was accomplished by the same procedure as during the previous test. Water in the collection tank was chlorinated to 20 mg/l immediately after all waste water was collected. The following day, after filtration and transfer to the storage tank, the water was again chlorinated to a level of 10 mg/l. Thus, during the first 6 days of testing, additional processing was not accomplished after chlorination of water in the storage tank. During the last 6 days, the charcoal adsorption process was accomplished after chlorination of water in the storage tank.

Results

Chemical/physical.- A detailed listing of the selected chemical/physical characteristics of the combined bath and laundry waste waters before processing is given in table XV. A listing after processing is given in table XVI. A listing of selected characteristics expected to be affected by the addition of the charcoal is presented in the following table:

Characteristic	With charcoal filter in recycle loop			With charcoal filter in line from pressure tank to commode		
	Before process	After process	Percent reduction	Before process	After process	Percent reduction
Conductivity, $\mu\text{mhos/cm}$	408	400	2	422	373	12
MBAS, mg/l	60	11	82	55	25	55
Odor, threshold number	2.0	1.5	25	2.8	2.2	22
Suspended solids, mg/l	77	32	58	56	30	46
Total organic carbon, mg/l	85	32	62	124	62	50
Total solids, mg/l	500	394	21	577	431	25
Turbidity (SiO_2 equiv.), mg/l	80	30	62	83	45	46

Shown in the table are the average values from tables XV and XVI of selected characteristics before and after processing with the charcoal filter in two different locations. Since the objective of adding the charcoal filter to the reuse loop system was to obtain a greater reduction in the values of MBAS and other selected characteristics, a comparison of reuse loop systems with and without the charcoal is necessary. The comparison is made by showing the average percent change between the values before and the values after processing for each respective test:

Characteristic	Percent decrease in characteristics after processing by -		
	Diatomaceous earth	Diatomaceous earth and charcoal in recycle loop	Diatomaceous earth and charcoal in line from tank to commode
Conductivity, $\mu\text{mhos/cm}$	13	12	12
MBAS, mg/l	6	82	66
Odor, threshold number	15	0	21
Suspended solids, mg/l	No data	58	46
Total organic carbon, mg/l	21	62	50
Total solids, mg/l	16	21	25
Turbidity (SiO_2 equiv.), mg/l	49	62	46

The charcoal filter was very effective in reducing the MBAS concentration. It was also effective in reducing most of the physical characteristics selected for analyses. The system configuration with the charcoal filter in the recycle loop shows a slight advantage over the configuration with the charcoal filter in the line from the pressure tank to the commode. Subjectively there was a noticeable improvement in the appearance of the water when charcoal

filtration was added to the reuse loop; however, differences due to the two alternate locations for the charcoal filter could not be subjectively detected.

Microbiological.- A detailed listing of the total and coliform microbial counts in the collection tank, storage tank, and commode tank is given in table XVII. Total counts in samples from the commode tank were reduced to and maintained at zero by the chlorination during the first 6 days of the test. During the last 6 days, when the charcoal filter was inserted between the storage tank and the commode tank, total counts increased abruptly and maintained a high level. Counts ranged between 4.4×10^2 and 5.1×10^6 cells/ml. Coliform counts in samples from the commode tank were also reduced to zero during the first 6 days and increased during the last 6 days. Coliform counts ranged between 1.0×10^1 and 1.0×10^3 coliforms/100 ml during the last 6 days. These results demonstrate that a charcoal filter should not be inserted between the location of final chlorination, the storage tank, and the location of use.

Water and energy use.- Water use-rate data were obtained for calculation of the relationship between waters available and waters used. These data are presented in table XVIII and are summarized below.

	12-day total	
	liters	gallons
Flush water required	2507.5	662.5
Combined bath and laundry waters available . .	2927.7	773.5
Makeup tap water	547.6	144.7
Collection tank overflow	15.1	4.0
Water withdrawn for samples	90.8	24.0
Collection tank drain	862.8	228.0

From equation (1), the expected water balance is

In units of liters:

$$2507.5 \approx 2927.7 + 547.6 - 15.1 - 90.8 - 862.8 - 0$$

$$2507.5 \approx 2506.6$$

In units of gallons:

$$662.5 \approx 773.5 + 144.7 - 4.0 - 24.0 - 228.0 - 0$$

$$662.5 \approx 662.2$$

Again, as during the 12-day Diatomaceous Earth Filtration and Chlorine Sterilization Test in which the shallow-trap commode was used, the volume of waste water available was greater than the volume required for commode flushing. However, makeup water again had to be added to compensate for losses. Overflow loss was significantly reduced but the loss due to tankage drain for daily washout of particulates increased. In order to make the system operational without addition of makeup water, the volume of water used for tank drainage would need to be reduced. This could be accomplished by decreasing the slope of the bottom of the collection tank and lowering the location of the suction line exiting the tank. It is estimated that washout of the particulates could be accomplished with 18.9 l (5 gal) of water.

The energy-using components for this system were the same as those used during the 12-day Diatomaceous Earth Filtration and Chlorine Sterilization Test. Use rates were identical and, therefore, will not be restated.

CONCLUSIONS

Results of an experimental investigation to determine the feasibility of reusing processed domestic bath and laundry water for commode flushing water are summarized as follows:

1. Bath and laundry waters that have been processed by diatomaceous earth filtration and chlorine sterilization are subjectively suitable for use as commode flush water. An additional improvement in the acceptability of the processed water can be made by adding a charcoal filter to lower the concentration of organics and reduce turbidity. Diatomaceous earth filtration is effective in removing particulates above 1 μm in size.

2. Counts of coliform organisms in bath and laundry waters can be reduced to zero or near zero by heating the water to a temperature of 335.9 K (145° F) for 30 min or by chlorinating the waters to a chlorine concentration of 20 mg/l. If additional processing is accomplished after the initial chlorination, subsequent chlorination to a concentration level not greater than 10 mg/l may be required.

3. The volume of bath and laundry waters available from a typical family of four is significantly greater than the volume of water required for commode flushing when the water-conserving, shallow-trap commode is used. Losses due to collection-tank overflow and tank drainage to remove accumulated particulates will reduce the volume of waste water available and possibly result in the need for a small volume of makeup tap water.

4. The amount of energy required to operate a typical system reusing bath and laundry waters for commode flushing is low. A system using diatomaceous earth filtration and chlorine sterilization to process the waters for reuse required an average of 0.695 kWh/day.

Langley Research Center
National Aeronautics and Space Administration
Hampton, Va. 23665
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TABLE I.- TECHNIQUES AND DETECTION LIMITS FOR
CHEMICAL/PHYSICAL ANALYSES OF WATER

Characteristic	Unit	Lower detection limit (a)	Technique and/or instrument
Metals			
Barium	mg/l	1	Atomic absorption
Boron	mg/l	1	Atomic absorption
Cadmium	mg/l	.005	Atomic absorption
Chromium	mg/l	.01	Atomic absorption
Copper	mg/l	.1	Atomic absorption
Iron	mg/l	.2	Atomic absorption
Lead	mg/l	.05	Atomic absorption
Magnesium	mg/l	.001	Atomic absorption
Manganese	mg/l	.01	Atomic absorption
Mercury	mg/l	.001	Atomic absorption
Nickel	mg/l	.1	Atomic absorption
Silver	mg/l	.01	Atomic absorption
Zinc	mg/l	.05	Atomic absorption
Ions			
Ammonia (N)	mg/l	0.05	Specific ion electrode
Calcium	mg/l	.1	Atomic absorption
Chloride	mg/l	5	Specific ion electrode
Chlorine	mg/l	.05	Colorimetric
Cyanide	mg/l	.02	Specific ion electrode
Fluoride	mg/l	.10	Specific ion electrode
Nitrate/nitrite	mg/l	.05	Colorimetric
Phosphates	mg/l	.05	Colorimetric
Potassium	mg/l	.05	Atomic absorption
Sodium	mg/l	.1	Atomic absorption
Sulfate	mg/l	5	Colorimetric

See footnote at end of table, p. 23.

TABLE I.- Concluded

Characteristic	Unit	Lower detection limit (a)	Technique and/or instrument
Organics			
MBAS ^b	mg/l	0.01	Colorimetric
Total organic carbon	mg/l	5	Total carbon analyzer
Urea	mg/l	1	Colorimetric
Physical properties			
Color ^c	PtCl ₆ equiv. units	5	Colorimetric
Conductivity	μmhos/cm	.4	Conductivity meter
Odor	Threshold number	-----	Dilution/subjective
pH	pH units	1	pH meter
Suspended solids	mg/l	10	Filtration-gravimetric
Total solids	mg/l	100	Gravimetric
Turbidity (SiO ₂ equiv.)	mg/l	.1	Turbidimeter

^aThe lower detection limits shown represent the current laboratory capability. Detection limits at higher values than these are indicated in some of the data tables. At the time of analyses, the limits were not as low as those stated in table I.

^bMethylene blue active substance; the test for determining the presence of a substance that reacts with methylene blue is used to indicate the presence of surfactants in soaps and detergents.

^cThe standard method of comparing water color in equivalent units of PtCl₆ is most applicable to natural waters. When artificial colors are introduced, such as those originating from detergents and coloring dyes, the method is not appropriate. Subjective analyses of the presence of color are often substituted.

TABLE II.— CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND LAUNDRY WATER
BEFORE AND AFTER SINGLE-PASS DIATOMACEOUS EARTH FILTRATION (TEST A)

(a) Metals

Characteristic	Unit	Test day 1		Test day 2		Test day 3		Average, days 1 to 3	
		Before filter	After filter	Before filter	After filter	Before filter	After filter	Before filter	After filter
Barium	mg/l	a	a	a	a	a	a	a	a
Boron	mg/l	a	a	a	a	a	a	a	a
Cadmium	mg/l	a	a	a	a	a	a	a	a
Chromium	mg/l	a	a	a	a	a	a	a	a
Copper	mg/l	0.1	0.1	a	0.2	a	0.2	a	0.2
Iron	mg/l	.3	.3	0.4	.2	0.3	.3	0.3	.3
Lead	mg/l	a	a	a	a	a	a	a	a
Magnesium	mg/l	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2
Manganese	mg/l	a	a	a	a	a	a	a	a
Mercury	mg/l	a	a	a	a	a	a	a	a
Nickel	mg/l	a	a	a	a	a	a	a	a
Silver	mg/l	a	a	a	a	a	a	a	a
Zinc	mg/l	.45	.45	.63	.70	.84	.91	.64	.69

See footnotes at end of table, p. 26.

TABLE II.- Continued

(b) Ions

Characteristic	Unit	Test day 1		Test day 2		Test day 3		Average, days 1 to 3	
		Before filter	After filter	Before filter	After filter	Before filter	After filter	Before filter	After filter
Ammonia (N)	mg/l	0.15	0.18	a	a	0.12	a	0.10	0.09
Calcium	mg/l	23	23	25	21	24	22	24	22
Chloride	mg/l	17	17	16	16	17	20	17	18
Chlorine	mg/l	a	a	a	a	a	a	a	a
Cyanide	mg/l	a	a	a	a	a	a	a	a
Fluoride	mg/l	.64	.64	.50	.60	.53	.56	.56	.60
Nitrate/nitrite	mg/l	.5	.5	a	a	a	a	.3	.3
Phosphates	mg/l	1.2	1.1	95.0	62.0	110.0	90	69.0	51.0
Potassium	mg/l	5.5	4.5	5.5	5.0	5.5	5.0	5.5	4.8
Sodium	mg/l	21	24	64	48	71	66	52	46
Sulfate	mg/l	103	69	116	77	127	103	115	83

See footnotes at end of table, p. 26.

TABLE II.- Concluded

(c) Organics and physical properties

Characteristic	Unit	Test day 1		Test day 2		Test day 3		Average, days 1 to 3	
		Before filter	After filter	Before filter	After filter	Before filter	After filter	Before filter	After filter
MBAS	mg/l	31	20	36	21	39	36	35	26
Total organic carbon	mg/l	161	159	147	35	168	112	159	102
Urea	mg/l	a	a	a	a	a	a	a	a
Color	Subjective	Brown	Brown	Brown	Brown	Brown	Brown	b	b
Conductivity	μ mhos/cm	174	160	321	260	340	330	278	250
Odor	Threshold number	<3	<3	<3	<3	<3	<3	<3	<3
pH	pH units	7.8	7.7	7.8	7.7	7.2	7.0	7.6	7.5
Suspended solids	mg/l	<100	<100	<100	<100	<100	<100	<100 ^c	<100 ^c
Total solids	mg/l	332	236	432	344	552	480	439	353
Turbidity (SiO ₂ equiv.)	mg/l	250	170	120	97	160	105	177	124

^aConcentrations were below the lower detection limit.

^bThe standard method of comparing water color in equivalent units of PtCl₆ is most applicable to natural waters. When artificial colors are introduced, such as those originating from detergents and coloring dyes, the method is not appropriate. Subjective analyses of the presence of color are often substituted.

^cThe lower detection limits shown represent the current laboratory capability. Detection limits at higher values than these are indicated in some of the data tables. At the time of analyses, the limits were not as low as those stated in table I.

TABLE III.— CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND
LAUNDRY WATER BEFORE AND AFTER 120-MIN RECYCLE
DIATOMACEOUS EARTH FILTRATION (TEST B)

(a) Metals

Characteristic	Unit	Test day 1		Test day 2		Average, ^b days 1 and 2	
		Before filter	After filter	Before filter	After filter	Before filter	After filter
Barium	mg/l	a	a	a	a	a	a
Boron	mg/l	a	a	a	a	a	a
Cadmium	mg/l	a	a	a	a	a	a
Chromium	mg/l	a	a	a	a	a	a
Copper	mg/l	a	0.2	0.1	0.1	a	0.2
Iron	mg/l	0.2	a	.2	.1	0.2	a
Lead	mg/l	a	a	a	a	a	a
Magnesium	mg/l	1.3	1.2	1.2	1.2	1.3	1.2
Manganese	mg/l	a	a	a	a	a	a
Mercury	mg/l	a	a	a	a	a	a
Nickel	mg/l	a	a	a	a	a	a
Silver	mg/l	a	a	a	a	a	a
Zinc	mg/l	.3	.2	.5	.6	.4	.4

(b) Ions

Ammonia (N)	mg/l	a	a	a	a	a	a
Calcium	mg/l	27	17	23	20	25	18
Chloride	mg/l	17	14	17	15	17	14
Chlorine	mg/l	a	a	a	a	a	a
Cyanide	mg/l	a	a	a	a	a	a
Fluoride	mg/l	.48	.50	.50	.54	.49	.52
Nitrate/nitrite	mg/l	a	a	a	a	a	a
Phosphates	mg/l	1.1	.7	75	45	38	23
Potassium	mg/l	11	11	5	5	8	8
Sodium	mg/l	19	19	49	37	34	28
Sulfate	mg/l	24	24	49	48	36	36

See footnotes at end of table, p. 28.

TABLE III.- Concluded
(c) Organics and physical properties

Characteristic	Unit	Test day 1		Test day 2		Average, ^b days 1 and 2	
		Before filter	After filter	Before filter	After filter	Before filter	After filter
MBAS	mg/l	9	15	42	15	26	15
Total organic carbon	mg/l	173	27	37	21	105	24
Urea	mg/l	a	a	a	a	a	a
Color	Subjective	Gray	Light gray	Brown	Gray	c	c
Conductivity	μmhos/cm	175	175	270	240	222	208
Odor	Threshold number	<3	<3	<3	<3	<3	<3
pH	pH units	7.2	7.4	7.2	7.2	7.2	7.3
Suspended solids	mg/l	<100	<100	<100	<100	<100 ^d	<100 ^d
Total solids	mg/l	339	187	405	240	372	214
Turbidity (SiO ₂ equiv.)	mg/l	230	60	90	25	160	42

^aConcentrations were below the lower detection limit.

^bThe before-filter sample on test day 3 was destroyed; therefore, the after-filter sample has been omitted. Averages are based on data from days 1 and 2.

^cThe standard method of comparing water color in equivalent units of PtCl₆ is most applicable to natural waters. When artificial colors are introduced, such as those originating from detergents and coloring dyes, the method is not appropriate. Subjective analyses of the presence of color are often substituted.

^dThe lower detection limits shown represent the current laboratory capability. Detection limits at higher values than these are indicated in some of the data tables. At the time of analyses, the limits were not as low as those stated in table I.

TABLE IV.- CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND
LAUNDRY WATER BEFORE AND AFTER 90-MIN
RECYCLE DIATOMACEOUS EARTH FILTRATION (TEST C)

(a) Metals

Characteristic	Unit	Test day 1		Test day 2		Test day 3		Average, days 1 to 3	
		Before filter	After Filter	Before filter	After filter	Before filter	After filter	Before filter	After filter
Barium	mg/l	a	a	a	a	a	a	a	a
Boron	mg/l	a	a	a	a	a	a	a	a
Cadmium	mg/l	a	a	a	a	a	a	a	a
Chromium	mg/l	a	a	a	a	a	a	a	a
Copper	mg/l	0.2	0.3	0.2	0.6	0.3	0.8	0.2	0.6
Iron	mg/l	a	a	.5	.5	.4	.4	.3	.3
Lead	mg/l	a	a	a	a	a	a	a	a
Magnesium	mg/l	1.4	1.3	1.5	1.4	1.6	1.5	1.5	1.4
Manganese	mg/l	a	a	a	a	a	a	a	a
Mercury	mg/l	a	a	a	a	a	a	a	a
Nickel	mg/l	a	a	a	a	a	a	a	a
Silver	mg/l	a	a	a	a	a	a	a	a
Zinc	mg/l	.6	.4	.6	.8	.7	.9	.6	.7

See footnotes at end of table, p. 31.

TABLE IV.- Continued

(b) Ions

Characteristic	Unit	Test day 1		Test day 2		Test day 3		Average, days 1 to 3	
		Before filter	After filter	Before filter	After filter	Before filter	After filter	Before filter	After filter
Ammonia (N)	mg/l	0.26	0.23	a	a	a	a	0.11	0.10
Calcium	mg/l	28	22	27	23	30	24	28	23
Chloride	mg/l	32	30	32	32	40	40	35	34
Chlorine	mg/l	2.1	.5	1.0	.4	a	a	1.0	.3
Cyanide	mg/l	a	a	a	a	a	a	a	a
Fluoride	mg/l	.70	.70	.71	.70	.70	.70	.70	.70
Nitrate/nitrite	mg/l	a	a	a	a	a	a	a	a
Phosphates	mg/l	2	1	75	55	95	85	57	47
Potassium	mg/l	7	6	4	5	4	4	5	5
Sodium	mg/l	22	22	54	15	68	62	48	33
Sulfate	mg/l	32	33	60	49	60	62	51	48

See footnotes at end of table, p. 31.

TABLE IV.- Concluded

(c) Organics and physical properties

Characteristic	Unit	Test day 1		Test day 2		Test day 3		Average, days 1 to 3	
		Before filter	After filter	Before filter	After filter	Before filter	After filter	Before filter	After filter
MBAS	mg/l	9	9	48	12	24	13	27	11
Total organic carbon	mg/l	49	37	46	21	64	31	53	30
Urea	mg/l	2	1	1	1	a	a	1	1
Color	Subjective	Gray	Gray	Gray	Gray	Brown	Light brown	b	b
Conductivity	μ mhos/cm	170	230	330	300	340	360	280	297
Odor	Threshold number	<3	<3	<3	<3	<3	<3	<3	<3
pH	pH units	7.3	7.2	7.1	7.4	7.1	7.6	7.2	7.4
Suspended solids	mg/l	<100	<100	<100	<100	<100	<100	<100 ^c	<100 ^c
Total solids	mg/l	412	309	444	273	540	471	465	351
Turbidity (SiO ₂ equiv.)	mg/l	240	60	60	35	100	30	133	42

^aConcentrations were below the lower detection limit.^bThe standard method of comparing water color in equivalent units of PtCl₆ is most applicable to natural waters. When artificial colors are introduced, such as those originating from detergents and coloring dyes, the method is not appropriate. Subjective analyses of the presence of color are often substituted.^cThe lower detection limits shown represent the current laboratory capability. Detection limits at higher values than these are indicated in some of the data tables. At the time of analyses, the limits were not as low as those stated in table I.

TABLE V.— PARTICULATE REMOVAL BY WOUND COTTON FIBER FILTERS
WHEN PRECEDED AND WHEN NOT PRECEDED BY
DIATOMACEOUS EARTH FILTRATION

Particle size removal rating of fiber filter, μm	Without prefiltration by diatomaceous earth (data from ref. 4)			With prefiltration by diatomaceous earth		
	Volume of water processed		Weight of particles removed, g	Volume of water processed		Weight of particles removed, g
	liters	gallons		liters	gallons	
50	} 2294	606	{ 32 47 46 109 64	} 2339	618	{ 0 .5 0 .5 0
25						
10						
5						
1						
Total	2294	606	298	2339	618	1.0

TABLE VI.- LINE PRESSURES WITHIN WOUND COTTON FIBER FILTER ASSEMBLY
WHEN PRECEDED BY DIATOMACEOUS EARTH FILTRATION

Daily total accumulative water processed		Average daily line pressure at pressure gage ^a -												Average process rate	
		P1		P2		P3		P4		P5		P6			
liters	gallons	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	l/hr	gal/hr
322	85	269	39	248	36	234	34	214	31	179	26	76	11	1287	340
632	167	276	40	248	36	234	34	221	32	179	26	76	11	1033	273
954	252	276	40	248	36	234	34	214	31	179	26	69	10	1007	266
1275	337	276	40	248	36	234	34	221	32	179	26	62	9	1071	283
1590	420	276	40	255	37	241	35	221	32	172	25	48	7	848	224
1824	482	276	40	248	36	234	34	214	31	172	25	48	7	1022	270
2044	540	276	40	248	36	241	35	221	32	165	24	48	7	878	232
2339	618	276	40	255	37	241	35	221	32	165	24	41	6	776	205

^aSee figure 5 for gage locations.

TABLE VII.- LINE PRESSURES WITHIN WOUND COTTON FIBER FILTER ASSEMBLY
WHEN NOT PRECEDED BY DIATOMACEOUS EARTH FILTRATION
(DATA FROM REF. 4)

Daily total accumulative water processed		Average daily line pressure at pressure gage ^a -														Average process rate	
		P1		P2		P3		P4		P5		P6					
liters	gallons	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	kN/m ²	psig	l/hr	gal/hr		
299	79	152	22	145	21	138	20	138	20	117	17	7	1	333	88		
594	157	310	45	296	43	290	42	283	41	227	33	14	2	356	94		
882	233	372	54	372	54	358	52	345	50	276	40	0	0	269	71		
b882	b233																
1185	313	276	40	255	37	221	32	221	32	186	27	62	9	727	192		
1491	394	276	40	255	37	241	35	221	32	165	24	14	2	439	116		
1798	475	276	40	255	37	241	35	221	32	138	20	0	0	216	57		
2104	556	276	40	248	36	234	34	207	30	110	16	0	0	132	35		
b2294	b606																
2407	636	276	40	255	37	241	35	221	32	131	19	21	3	140	37		
2733	722	276	40	248	36	227	33	200	29	138	20	83	12	848	224		
3054	807	276	40	241	35	221	32	200	29	110	16	55	8	666	176		
3304	873	276	40	234	34	214	31	200	29	62	9	14	2	390	103		

^aSee figure 5 for gage locations.

^bAll 5 wound cotton fiber filters replaced because of restricted flow.

TABLE VIII.- TOTAL AND COLIFORM ORGANISMS IN BATH AND LAUNDRY
WASTE WATER BEFORE AND AFTER HEAT STERILIZATION

Test day	Test condition	Sample location	Total micro-organism count, cells/ml	Coliform organism count, coliforms/100 ml
Before test	Tap water Tap water Hot tap water, 350.9 K (172° F)	Collection tank Storage tank Hot water tank	7.6×10^2 5.87×10^4 0	a a 0
1	Unprocessed	Collection tank	3.77×10^4	2.9×10^4
	Filtered	Storage tank	8.4×10^4	3.0×10^3
	Heated:			
	335.9 K (145° F) for 15 min 335.9 K (145° F) for 30 min 335.9 K (145° F) for 45 min	Hot water tank Hot water tank Hot water tank	0 0 0	0 0 0
2	Unprocessed	Collection tank	3.05×10^6	8.0×10^6
	Filtered	Storage tank	4.44×10^6	8.0×10^6
	Heated:			
	330.4 K (135° F) for 15 min 330.4 K (135° F) for 30 min 330.4 K (135° F) for 45 min	Hot water tank Hot water tank Hot water tank	3.0×10^0 1.0×10^0 7.0×10^0	4.0×10^0 0 5.6×10^1
3	Unprocessed	Collection tank	No data	No data
	Filtered	Storage tank	7.7×10^6	2.5×10^7
	Heated:			
	335.9 K (145° F) for 15 min 335.9 K (145° F) for 30 min 335.9 K (145° F) for 45 min	Hot water tank Hot water tank Hot water tank	6.0×10^0 3.0×10^0 0	4.6×10^1 1.2×10^0 0

^aCould not be counted; without well-defined colonies.

TABLE IX.- TOTAL AND COLIFORM ORGANISMS IN BATH AND LAUNDRY
WASTE WATER BEFORE AND AFTER CHLORINE STERILIZATION

Test day	Test condition	Sample location	Total micro-organism count, cells/ml	Coliform organism count, coliforms/100 ml
Before test	Tap water Tap water Tap water	Collection tank Storage tank Commode tank	1.9×10^4 3.4×10^4 4.2×10^4	6.0×10^3 3.5×10^4 1.8×10^5
1	Unprocessed Chlorinated, 15 mg/l Chlorinated and filtered Chlorinated and filtered	Collection tank Collection tank Storage tank Commode tank: 8 a.m. 10 a.m. 12 m. 3 p.m.	4.6×10^4 9.3×10^1 3.5×10^2 2.4×10^4 7.2×10^3 5.1×10^3 3.9×10^2	5.3×10^4 0 0 4.3×10^5 1.2×10^4 9.7×10^3 6.1×10^3
2	Unprocessed Chlorinated, 20 mg/l Chlorinated and filtered Chlorinated and filtered	Collection tank Collection tank Storage tank Commode tank: 8 a.m. 10 a.m. 12 m. 3 p.m.	7.9×10^4 1.0×10^0 5.6×10^4 7.4×10^5 1.2×10^6 3.0×10^6 2.4×10^6	1.5×10^4 0 0 0 0 0 0
3	Unprocessed Chlorinated, 20 mg/l Chlorinated and filtered Chlorinated and filtered	Collection tank Collection tank Storage tank Commode tank: 8 a.m. 10 a.m. 12 m. 3 p.m.	2.2×10^5 0 3.7×10^3 1.8×10^6 1.4×10^6 1.6×10^6 7.3×10^5	0 0 0 0 0 0 0

TABLE X.- DAILY NUMBER OF TUB AND SHOWER BATHS, LAUNDRY LOADS,
AND COMMODE FLUSHES DURING 12-DAY DIATOMACEOUS EARTH
FILTRATION AND CHLORINATION STERILIZATION TEST

Day	Number of baths	Number of laundry loads	Schedule of commode flushes	
1	1 tub 1 shower	2	21 daily at	
2	1 tub 1 shower	0	a.m.	p.m.
3	1 tub 1 shower	2	8:30	12:15
4	1 tub 1 shower	1	9:00	1:15
5	1 tub 1 shower	2	9:10	3:15
6	1 tub 1 shower	1	9:20	3:45
7	1 tub 1 shower	0	9:30	4:15
8	1 tub 1 shower	1	10:00	4:45
9	1 tub 1 shower	1	10:45	5:30
10	1 tub 1 shower	1	11:30	5:50
11	1 tub 1 shower	1		6:00
12	None	None		6:10
				6:20
				6:30
				6:50

TABLE XI.- CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND
LAUNDRY WATER BEFORE DIATOMACEOUS EARTH FILTRATION
AND CHLORINE STERILIZATION

(a) Metals

Characteristic	Unit	Test day											
		1	2	3	4	5	6	7	8 (b)	9	10	11	12 (c)
Barium	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Boron	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Cadmium	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Chromium	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Copper	mg/l	0.2	0.2	0.2	0.2	0.2	0.1	0.2	---	0.2	0.1	0.4	
Iron	mg/l	.7	.3	.5	.3	.3	.8	.2	---	.4	.4	.7	
Lead	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Magnesium	mg/l	1.5	2.0	1.6	1.4	1.9	1.8	1.5	---	1.5	1.5	1.6	
Manganese	mg/l	.05	.06	.06	.06	.05	.05	.05	---	a	a	a	
Mercury	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Nickel	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Silver	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Zinc	mg/l	.5	.5	.5	.5	.7	.7	.4	---	.6	.5	.5	

See footnotes at end of table, p. 40.

TABLE XI.- Continued

(b) Ions

Characteristic	Unit	Test day											
		1	2	3	4	5	6	7	8 (b)	9	10	11	12 (c)
Ammonia (N)	mg/l	0.13	1.5	0.42	0.76	a	0.76	0.09	---	1.4	1.6	1.4	
Calcium	mg/l	28	31	31	29	31	30	29	---	29	28	29	
Chloride	mg/l	13	26	15	20	23	29	17	---	22	23	23	
Chlorine	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Cyanide	mg/l	a	a	a	a	a	a	a	---	a	a	a	
Fluoride	mg/l	.72	.76	.76	.74	.76	.78	.74	---	.48	.52	.66	
Nitrate/nitrite	mg/l	a	1.1	a	a	a	.3	.3	---	.5	a	a	
Phosphates	mg/l	165	9	160	185	175	200	30	---	150	175	130	
Potassium	mg/l	2.5	11.0	4.5	3.5	9.0	4.5	3.0	---	5.5	6.5	6.0	
Sodium	mg/l	92	18	91	105	95	114	10	---	89	97	74	
Sulfate	mg/l	80	43	77	76	62	81	10	---	58	66	49	

See footnotes at end of table, p. 40.

TABLE XI.— Concluded

(c) Organics and physical properties

Characteristic	Unit	Test day											
		1	2	3	4	5	6	7	8 (b)	9	10	11	12 (c)
MBAS	mg/l	51	0.19	60	96	60	63	0.23	---	83	72	33	
Total organic carbon	mg/l	48	29	38	32	47	54	11	---	59	48	66	
Urea	mg/l	a	15.0	a	2.0	a	1.8	a	---	2.2	2.2	4.6	
Color	Subjective	Brown	Brown	Brown	Brown	Brown	Brown	Gray	---	Brown	Gray	Brown	
Conductivity	μmhos/cm	440	280	420	480	480	530	200	---	440	460	410	
Odor	Threshold number	3	2	4	3	3	2	2	---	2	0	1	
pH	pH units	7.9	6.9	7.0	8.4	7.9	8.0	7.1	---	8.0	8.1	7.7	
Suspended solids	mg/l	<100 ^d	<100	<100	<100	<100	128	<100	---	<100	<100	<100	
Total solids	mg/l	634	323	569	568	668	783	183	---	609	622	532	
Turbidity (SiO ₂ equiv.)	mg/l	27	22	50	30	240	51	10	---	48	32	41	

^aConcentrations were below the lower detection limit.^bSample discarded because water was chlorinated prior to sample withdrawal.^cWaste water was not produced or collected on day 12, since, according to test procedures, it would be processed and used on the following day.^dThe lower detection limits shown represent the current laboratory capability. Detection limits at higher values than these are indicated in some of the data tables. At the time of analyses, the limits were not as low as those stated in table I.

TABLE XII.- CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND
LAUNDRY WATER AFTER DIATOMACEOUS EARTH FILTRATION
AND CHLORINE STERILIZATION

(a) Metals

Characteristic	Unit	Test day											
		1 (b)	2	3	4	5	6	7	8	9	10	11	12
Barium	mg/l		a	a	a	a	a	a	a	a	a	a	a
Boron	mg/l		a	a	a	a	a	a	a	a	a	a	a
Cadmium	mg/l		a	a	a	a	a	a	a	a	a	a	a
Chromium	mg/l		a	a	a	a	a	a	a	a	a	a	a
Copper	mg/l		0.4	0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.4
Iron	mg/l		.6	.5	.4	.4	.3	.4	.4	.2	.6	.4	.4
Lead	mg/l		a	a	a	a	a	a	a	a	a	a	a
Magnesium	mg/l		1.6	1.7	1.6	1.6	1.7	1.8	1.7	1.7	1.7	1.7	1.7
Manganese	mg/l		.06	.06	.06	.06	a	.05	a	a	a	a	a
Mercury	mg/l		a	a	a	a	a	a	a	a	a	a	a
Nickel	mg/l		a	a	a	a	a	a	a	a	a	a	a
Silver	mg/l		a	a	a	a	a	a	a	a	a	a	a
Zinc	mg/l		.7	.5	.6	.5	.6	.6	.6	.7	.6	.6	.7

See footnotes at end of table, p. 43.

TABLE XII.- Continued

(b) Ions

Characteristic	Unit	Test day											
		1	2	3	4	5	6	7	8	9	10	11	12
Ammonia (N)	mg/l	(b)	0.10	0.56	2.9	0.24	0.22	0.13	0.21	1.5	0.9	0.6	1.5
Calcium	mg/l		27	20	31	25	26	26	26	26	26	26	29
Chloride	mg/l		14	25	25	24	27	26	24	24	26	25	28
Chlorine	mg/l		.35	.45	.38	.38	.37	.59	.55	<0.05	.30	.30	<0.05
Cyanide	mg/l		a	a	a	a	a	a	a	a	a	a	a
Fluoride	mg/l		.68	.72	.74	.73	.75	.75	.74	.63	.52	.52	.58
Nitrate/nitrite	mg/l		1.5	1.0	a	a	a	a	a	.4	a	a	a
Phosphates	mg/l		1.0	80	105	105	115	105	70	80	85	95	100
Potassium	mg/l		3.5	5.5	4.5	4.5	6.0	6.5	5.5	4.5	5.0	4.5	5.5
Sodium	mg/l		71	60	70	74	76	72	52	57	57	60	65
Sulfate	mg/l		.7	.5	.6	.5	.6	.6	.6	.7	.6	.6	.7

See footnotes at end of table, p. 43.

TABLE XII. - Concluded

(c) Organics and physical properties

Characteristic	Unit	Test day											
		1 (b)	2	3	4	5	6	7	8	9	10	11	12
MBAS	mg/l		24	15	36	132	36	210	24	21	21	36	27
Total organic carbon	mg/l		31	21	28	19	27	34	25	38	69	36	61
Urea	mg/l		3.7	10.2	2.5	4.8	4.2	4.8	4.0	1.3	6.0	3.6	3.3
Color	Subjective		Light brown	Light brown	Light brown	Brown	Brown	Light brown	Light gray	Light brown	Light brown	Brown	Light gray
Conductivity	μmhos/cm		360	360	390	380	390	380	330	350	360	370	390
Odor	Threshold number		2	2	3	2	2	2	2	1	2	0	0
pH	pH units		7.2	7.0	7.2	7.4	7.4	7.2	7.1	7.4	7.0	7.1	7.0
Suspended solids	mg/l		<100 ^c	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total solids	mg/l		400	470	436	638	544	514	368	391	389	450	459
Turbidity (SiO ₂ equiv.)	mg/l		15	10	17	22	50	42	35	40	28	27	32

^aConcentrations were below the lower detection limit.^bAnalyses not included since there were no analyses on the comparable waste water collected on the day prior to the test.^cThe lower detection limits shown represent the current laboratory capability. Detection limits at higher values than these are indicated in some of the data tables. At the time of analyses, the limits were not as low as those stated in table I.

TABLE XIII. — TOTAL AND COLIFORM ORGANISMS IN TANKAGE AND
COMMODE TANK DURING 12-DAY DIATOMACEOUS EARTH
FILTRATION AND CHLORINE STERILIZATION TEST

Test day	Time	Micro-organism count in sample from —					
		Collection tank		Storage tank		Commode tank	
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml
Preload	8:45 a.m.	Chlorine added, 20 mg/l					
1	8:00 a.m.					2.7×10^2	0
	9:00 a.m.						
	10:00 a.m.			4.41×10^3	1.0×10^2	1.69×10^3	1.0×10^1
	10:50 a.m.	2.0×10^5	4.0×10^5				
	11:00 a.m.	Chlorine added, 20 mg/l					
	12:00 m.					1.5×10^1	0
	3:00 p.m.					0	0
2	8:00 a.m.					2.0×10^1	0
	9:00 a.m.			4.1×10^4	0		
	10:00 a.m.					2.03×10^4	0
	11:15 a.m.			Chlorine added, 10 mg/l			
	12:00 m.					4.55×10^3	0
	3:00 p.m.	2.73×10^4	2.1×10^4			0	0
	6:30 p.m.	Chlorine added, 20 mg/l					
3	6:35 p.m.						
	8:00 a.m.					0	0
	8:50 a.m.			1.7×10^2	0		
	9:00 a.m.			Chlorine added, 10 mg/l			
	10:00 a.m.					0	0
	12:00 m.	1.05×10^6	5.1×10^6			4.0×10^1	0
	12:35 p.m.	Chlorine added, 20 mg/l					
	12:40 p.m.						
	3:00 p.m.					$<1.0 \times 10^1$	0

TABLE XIII. — Continued

Test day	Time	Micro-organism count in sample from —					
		Collection tank		Storage tank		Commode tank	
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml
4	8:00 a.m.					2.0×10^0	0
	9:00 a.m.			3.43×10^4	3.0×10^3		
	9:10 a.m.			Chlorine added, 10 mg/l		0	0
	10:00 a.m.						
	11:35 a.m.	2.88×10^5	6.0×10^5				
	11:40 a.m.	Chlorine added, 20 mg/l				0	0
	12:00 m.					0	0
5	3:00 p.m.						
	8:00 a.m.					3.5×10^0	0
	8:50 a.m.			3.54×10^3	0		
	9:00 a.m.			Chlorine added, 10 mg/l		0	0
	10:00 a.m.						
	11:30 a.m.	3.89×10^6	1.5×10^7				
	11:35 a.m.	Chlorine added, 20 mg/l				0	0
6	12:00 m.					0	0
	3:00 p.m.					0	0
	8:00 a.m.					3.8×10^1	0
	9:00 a.m.			6.0×10^4	1.0×10^4		
	9:30 a.m.			Chlorine added, 10 mg/l		2.0×10^4	a
	10:00 a.m.					0	0
	12:30 p.m.	Chlorine added, 20 mg/l				2.1×10^4	0

^aCould not be counted; without well-defined colonies.

TABLE XIII.— Continued

Test day	Time	Micro-organism count in sample from —					
		Collection tank		Storage tank		Commode tank	
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml
7	8:00 a.m.					5.0×10^1	0
	8:50 a.m.			3.36×10^5	4.0×10^4		
	9:15 a.m.			Chlorine added, 10 mg/l			
	10:00 a.m.					1.46×10^5	a
	12:00 m.					2.03×10^5	a
	12:05 p.m.						
8	12:10 p.m.					1.47×10^5	a
	3:00 p.m.						
	8:00 a.m.					1.09×10^5	0
	8:50 a.m.			3.39×10^4	3.6×10^4		
	9:00 a.m.			Chlorine added, 10 mg/l		0	0
	10:00 a.m.						
	11:55 a.m.					0	0
	12:00 m.					0	0
	3:00 p.m.					0	0
9	8:00 a.m.					1.76×10^2	0
	9:00 a.m.			3.55×10^4	1.3×10^4		
	9:05 a.m.			Chlorine added, 10 mg/l		0	0
	10:00 a.m.					0	0
	12:00 m.						
	1:00 p.m.			8.4×10^4	4.5×10^4		
	1:05 p.m.			Chlorine added, 20 mg/l		0	0
	3:00 p.m.						

^aCould not be counted; without well-defined colonies.

TABLE XIII. -- Concluded

Test day	Time	Micro-organism count in sample from --					
		Collection tank		Storage tank		Commode tank	
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml
10	8:00 a.m.					2.11×10^5	0
	9:00 a.m.			8.1×10^5	1.8×10^4		
	9:05 a.m.			Chlorine added, 10 mg/l		0	0
	10:00 a.m.		7.7×10^5				
	11:55 a.m.	5.60×10^5	Chlorine added, 20 mg/l			0	0
	12:00 m.					0	0
	12:00 m.					8.0×10^0	0
	3:00 p.m.						1.2×10^3
11	8:00 a.m.					2.61×10^6	
	9:00 a.m.			1.87×10^6	1.0×10^4		
	9:05 a.m.			Chlorine added, 10 mg/l		0	0
	10:00 a.m.		1.3×10^4				
	11:55 a.m.	6.03×10^4	Chlorine added, 20 mg/l				
	12:00 m.					0	0
	12:00 m.					0	0
	3:00 p.m.						
12	8:00 a.m.					1.74×10^3	0
	9:00 a.m.			2.99×10^6	9.2×10^4		
	9:05 a.m.			Chlorine added, 10 mg/l		0	0
	10:00 a.m.		No sample			0	0
	12:00 m.					0	0
	3:00 p.m.					0	0

TABLE XIV.— WATERS USED AND WASTE WATERS AVAILABLE DURING 12-DAY
DIATOMACEOUS EARTH FILTRATION AND CHLORINE STERILIZATION TEST

Test day	Flush water required		Combined bath and laundry water available		Collection tank water overflow		Collection tank water drained		Makeup water added	
	liters	gallons	liters	gallons	liters	gallons	liters	gallons	liters	gallons
Preload										
1	201.4	53.2	285.8	75.5	79.9	21.1	75.7	20.0	53.0	14.0
2	199.9	52.8	143.8	38.0	0	0	75.7	20.0	147.6	39.0
3	201.4	53.2	389.9	103.0	0	0	75.7	20.0	53.0	14.0
4	220.3	58.2	264.9	70.0	0	0	60.6	16.0	0	0
5	224.4	59.3	389.9	103.0	0	0	60.6	16.0	0	0
6	215.7	57.0	340.6	90.0	0	0	105.9	28.0	0	0
7	218.4	57.7	159.0	42.0	0	0	121.1	32.0	0	0
8	208.2	55.0	295.2	78.0	0	0	60.6	16.0	0	0
9	216.1	57.1	321.7	85.0	0	0	60.6	16.0	0	0
10	212.7	56.2	246.0	65.0	0	0	60.6	16.0	0	0
11	210.4	55.6	234.7	62.0	0	0	60.6	16.0	0	0
12	209.3	55.3	0	0	0	0	60.6	16.0	0	0
Total	2538.2	670.6	3541.2	935.6	79.9	21.1	878.3	232.0	253.6	67.0

TABLE XV.— CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND LAUNDRY WATER
BEFORE RECYCLE DIATOMACEOUS EARTH FILTRATION WITH CHARCOAL ADSORPTION
AND CHLORINE STERILIZATION

Characteristic	Unit	Test day					Av. for days 2 to 5	Test day					Av. for days 6 to 11		
		1 (a)	2	3	4	5		6	7	8	9	10		11	12 (b)
Color	Subjective	---	Brown	Brown	Gray	Brown	c	Brown	Brown	Gray	Brown	Brown	Gray		c
Conductivity	$\mu\text{mhos/cm}$	---	240	460	430	500	408	460	175	450	500	480	470		422
MBAS	mg/l	---	5	66	89	80	60	62	8	70	60	62	66		55
Odor	Threshold number	---	2	2	2	2	2	4	1	2	4	4	2		2.8
Phosphates	mg/l	---	2	170	140	180	123	170	1	160	170	170	150		137
Suspended solids	mg/l	---	87	71	58	92	77	67	50	39	44	92	45		56
Total organic carbon	mg/l	---	37	83	79	140	85	115	50	130	170	120	160		124
Total solids	mg/l	---	294	550	528	629	500	579	459	542	641	668	571		577
Turbidity (SiO ₂ equiv.)	mg/l	---	150	55	43	74	80	55	100	69	100	95	78		83

^aThe sample for day 1 was discarded because the collection tank was chlorinated prior to sample withdrawal.

^bWaste water was not produced or collected on day 12, since it would be processed and used subsequent to the last day (day 12).

^cThe standard method of comparing water color in equivalent units of PtCl_6 is most applicable to natural waters. When artificial colors are introduced, such as those originating from detergents and coloring dyes, the method is not appropriate. Subjective analyses of the presence of color are often substituted.

TABLE XVI.—CHEMICAL/PHYSICAL ANALYSES OF COMBINED BATH AND LAUNDRY WATER AFTER RECYCLE
DIATOMACEOUS EARTH FILTRATION WITH CHARCOAL ADSORPTION AND CHLORINE STERILIZATION

Characteristic	Unit	Test day						Av. for days 3 to 6	Test day					Av. for days 7 to 12	
		1 (a)	2 (b)	3	4	5	6		7	8	9	10	11		12
Color	Subjective (PtCl ₆ equiv. units ^c)	---	---	Tan (40)	Tan (40)	Light gray (30)	Brown (100)	(53)	Tan (50)	Tan (40)	Light gray (40)	Brown (70)	Tan (60)	Light gray (50)	(52)
Conductivity	μmhos/cm	---	---	400	340	400	460	400	440	450	320	360	330	340	373
MBAS	mg/l	---	---	5	10	11	19	11	23	30	17	22	23	33	25
Odor	Threshold number	---	---	1	2	1	2	1.5	2	4	2	2	1	2	2.2
Phosphates	mg/l	---	---	98	84	100	150	108	130	130	80	100	90	95	104
Suspended solids	mg/l	---	---	17	27	26	57	32	21	30	27	36	32	33	30
Total organic carbon	mg/l	---	---	23	29	21	54	32	50	63	50	66	75	67	62
Total solids	mg/l	---	---	398	341	394	443	394	219	497	336	643	456	435	431
Turbidity (SiO ₂ equiv.)	mg/l	---	---	28	28	22	40	30	42	42	33	49	56	47	45

^aAnalyses not included since there were no analyses on the comparable waste water collected on the day prior to the test.

^bAnalyses not included since the comparable waste water sample taken on day 1 was discarded. (See table XV.)

^cThese processed waters were the only ones whose color characteristic could be numerically quantified by the standard method of comparing to equivalent units of PtCl₆. (See footnote c, table I.)

TABLE XVII.— TOTAL AND COLIFORM ORGANISMS IN TANKAGE AND COMMODE TANK DURING
12-DAY TEST WITH DIATOMACEOUS EARTH FILTRATION, CHARCOAL ADSORPTION,
AND CHLORINE STERILIZATION

Test day	Time	Micro-organism count in sample from -								
		Collection tank		Storage tank		Commode tank				
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml			
Preload	11:20 a.m.	Chlorine added, 20 mg/l								
1	8:00 a.m.			4.8×10^4	1.5×10^3	1.4×10^5	0			
	9:40 a.m.			Chlorine added, 10 mg/l		1.5×10^5	1.0×10^2	0		
	9:45 a.m.									
	10:00 a.m.					0				
	12:00 m.	2.1×10^6	8.0×10^5							
	12:30 p.m.	Chlorine added, 20 mg/l								
	1:00 p.m.									
	3:00 p.m.					0	0			
2	8:00 a.m.			4.9×10^4	5.5×10^3	0	0			
	10:00 a.m.					0	0			
	11:00 a.m.			Chlorine added, 10 mg/l		0	0			
	11:15 a.m.									
	12:00 m.									
	3:00 p.m.	4.3×10^4	1.2×10^3							
	3:15 p.m.	Chlorine added, 20 mg/l				0	0			
	3:15 p.m.									
3	8:00 a.m.			0	0	0	0			
	9:40 a.m.			Chlorine added, 10 mg/l		0	0	0	0	
	9:45 a.m.									
	10:00 a.m.					0	0			
	12:00 m.	1.0×10^5	1.1×10^4							
	12:05 p.m.	Chlorine added, 20 mg/l								
	12:15 p.m.									
	3:00 p.m.					0	0			

TABLE XVII.— Continued

Test day	Time	Micro-organism count in sample from —					
		Collection tank		Storage tank		Commode tank	
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml
4	8:00 a.m.					0	0
	10:00 a.m.					0	0
	10:35 a.m.			7.0×10^0	0		
	10:45 a.m.			Chlorine added, 10 mg/l		0	0
	12:00 m.					0	0
	3:00 p.m.					0	0
	4:00 p.m.	2.4×10^5	9.0×10^3				
5	6:45 p.m.	Chlorine added, 20 mg/l					
	8:00 a.m.					0	0
	10:00 a.m.					0	0
	11:15 a.m.			0	0		
	11:25 a.m.			Chlorine added, 10 mg/l		0	0
	12:00 m.						
	1:55 p.m.	1.9×10^5	2.5×10^4				
6	2:10 p.m.	Chlorine added, 20 mg/l				0	0
	3:00 p.m.					0	0
	8:00 a.m.					0	0
	10:00 a.m.					0	0
	11:30 a.m.			2.1×10^2	0		
	11:37 a.m.			Chlorine added, 10 mg/l		0	0
	12:00 m.					0	0
	3:00 p.m.						
	3:15 p.m.	Chlorine added, 20 mg/l					
	4:00 p.m.	0 ^a	0 ^a				

^aWater in collection tank was chlorinated prior to sample withdrawal; therefore, micro-organism counts were zero.

TABLE XVII. — Continued

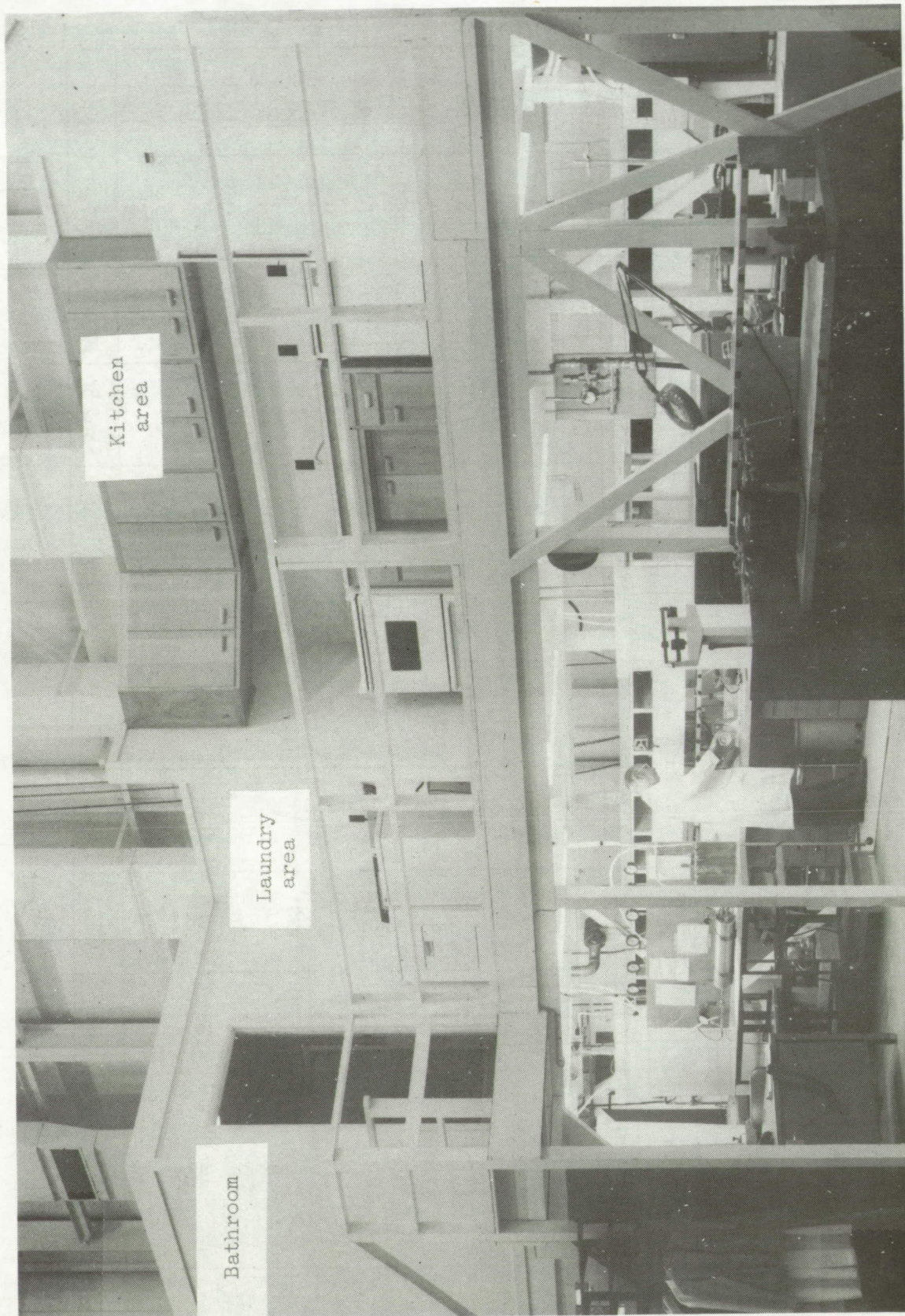
Test day	Time	Micro-organism count in sample from —					
		Collection tank		Storage tank		Commode tank	
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml
7	8:00 a.m.					3.6×10^3	0
	10:00 a.m.					4.4×10^2	6.0×10^2
	10:05 a.m.			0	0		
	10:25 a.m.			Chlorine added, 10 mg/l			
	12:00 m.					3.4×10^3	1.5×10^1
	3:00 p.m.					4.5×10^3	1.3×10^1
8	4:30 p.m.	3.3×10^5	1.1×10^4				
	4:35 p.m.	Chlorine added, 20 mg/l					
	8:00 a.m.					5.1×10^5	2.0×10^1
	9:20 a.m.			0	0		
	9:45 a.m.			Chlorine added, 10 mg/l			
	10:00 a.m.					8.1×10^4	1.0×10^2
	12:00 m.					1.8×10^5	1.0×10^2
	3:00 p.m.					1.1×10^5	1.0×10^2
9	3:20 p.m.	3.2×10^5	6.0×10^4				
	3:50 p.m.	Chlorine added, 20 mg/l					
	8:00 a.m.					1.1×10^6	1.0×10^2
	10:00 a.m.					9.9×10^4	3.0×10^2
	10:40 a.m.			6.4×10^3	6.0×10^0		
	10:45 a.m.			Chlorine added, 10 mg/l			
	12:00 m.					4.4×10^4	2.0×10^1
	1:55 p.m.	5.5×10^5	8.2×10^3				
	2:00 p.m.	Chlorine added, 20 mg/l					
	3:00 p.m.					4.4×10^4	2.0×10^1

TABLE XVII.— Concluded

Test day	Time	Micro-organism count in sample from —					
		Collection tank		Storage tank		Commode tank	
		cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml	cells/ml	coliforms/100 ml
10	8:00 a.m.					2.3×10^6	1.0×10^1
	10:00 a.m.					2.6×10^5	1.0×10^2
	10:25 a.m.						
	10:35 a.m.						
	12:00 m.			6.6×10^5	3.0×10^3		
	3:00 p.m.			Chlorine added, 10 mg/l			
	3:05 p.m.					6.1×10^4	1.0×10^2
11	3:10 p.m.	1.5×10^6	1.0×10^5			1.7×10^5	1.0×10^1
		Chlorine added, 20 mg/l					
	8:00 a.m.					5.1×10^6	
	9:45 a.m.			2.5×10^5	5.0×10^3		
	10:00 a.m.			Chlorine added, 10 mg/l			
	10:00 a.m.					5.7×10^5	6.0×10^2
	12:00 m.					8.5×10^5	6.0×10^2
12	12:10 p.m.	1.7×10^5	2.8×10^4				
	12:15 p.m.	Chlorine added, 20 mg/l					
	3:00 p.m.					3.6×10^5	1.0×10^3
	8:00 a.m.					6.3×10^5	2.0×10^2
	10:00 a.m.					4.6×10^5	4.0×10^2
	10:50 a.m.						
	11:00 a.m.	No sample		3.6×10^3	4.0×10^2		
	12:00 m.			Chlorine added, 10 mg/l		2.4×10^5	1.0×10^2
	3:00 p.m.					1.4×10^5	4.0×10^1

TABLE XVIII.— WATERS USED AND WASTE WATERS AVAILABLE DURING 12-DAY TEST
WITH DIATOMACEOUS EARTH FILTRATION, CHARCOAL ADSORPTION, AND
CHLORINE STERILIZATION

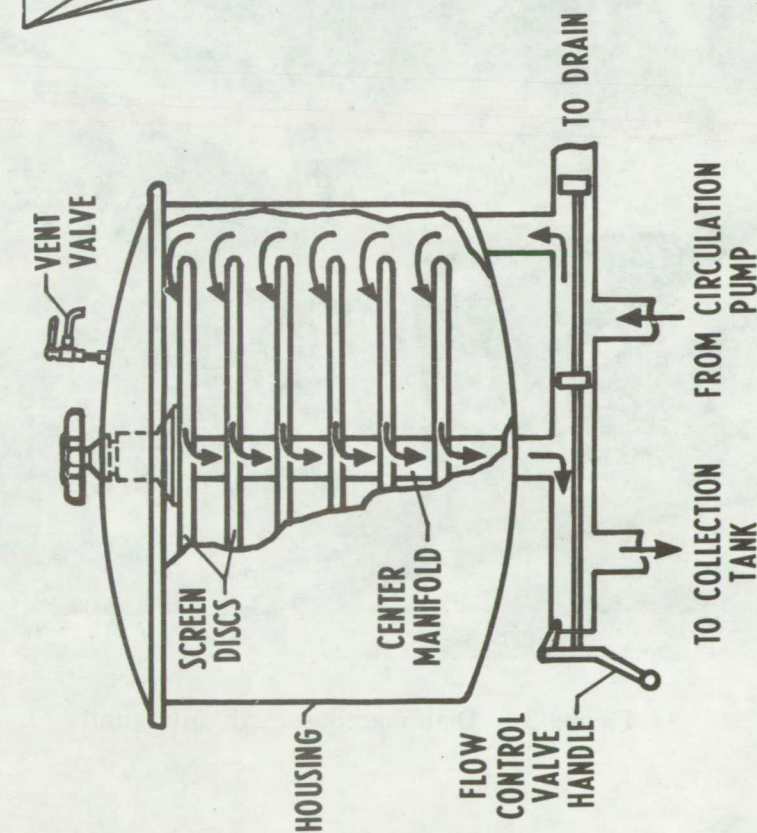
Test day	Flush water required		Combined bath and laundry water available		Collection tank water overflow		Collection tank water drained		Makeup water added	
	liters	gallons	liters	gallons	liters	gallons	liters	gallons	liters	gallons
Preload	-----	-----	234.7	62.0	0	0	0	0	0	0
1	203.6	53.8	386.1	102.0	0	0	71.9	19.0	39.4	10.4
2	196.1	51.8	87.1	23.0	0	0	71.9	19.0	98.8	26.1
3	201.7	53.3	370.9	98.0	0	0	71.9	19.0	53.7	14.2
4	213.8	56.5	242.3	64.0	0	0	71.9	19.0	43.9	11.6
5	213.8	56.5	370.9	98.0	0	0	71.9	19.0	0	0
6	215.4	56.9	215.7	57.0	15.1	4.0	71.9	19.0	0	0
7	212.7	56.2	90.8	24.0	0	0	71.9	19.0	0	0
8	206.7	54.6	217.6	57.5	0	0	71.9	19.0	138.1	36.5
9	214.6	56.7	223.3	59.0	0	0	71.9	19.0	70.8	18.7
10	205.5	54.3	253.6	67.0	0	0	71.9	19.0	69.6	18.4
11	208.2	55.0	234.7	62.0	0	0	71.9	19.0	33.3	8.8
12	215.4	56.9	0	0	0	0	71.9	19.0	0	0
Total	2507.5	662.5	2927.7	773.5	15.1	4.0	862.8	228.0	547.6	144.7



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Figure 1.— Domestic water reuse and waste treatment test facility.

SCREEN DISC ASSEMBLY AND HOUSING



SCREEN DISC ASSEMBLY

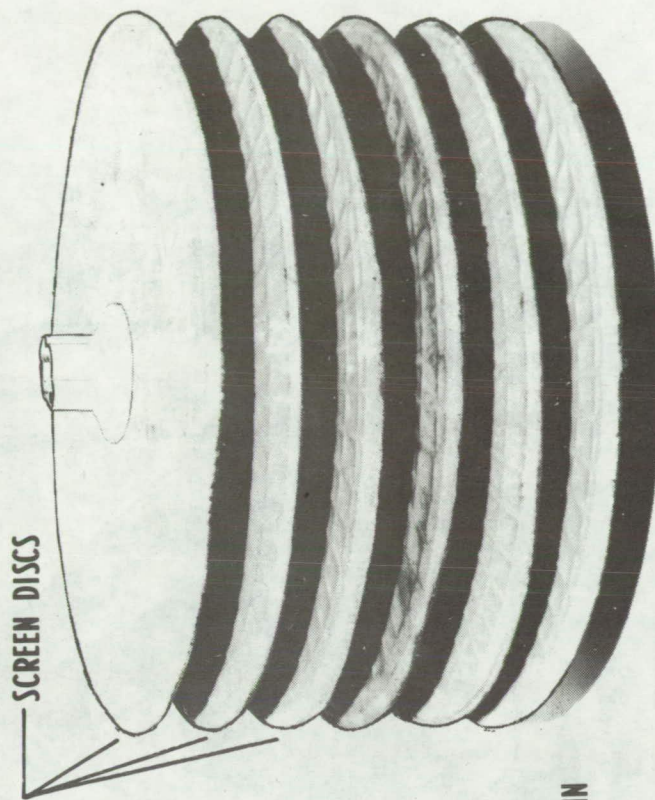
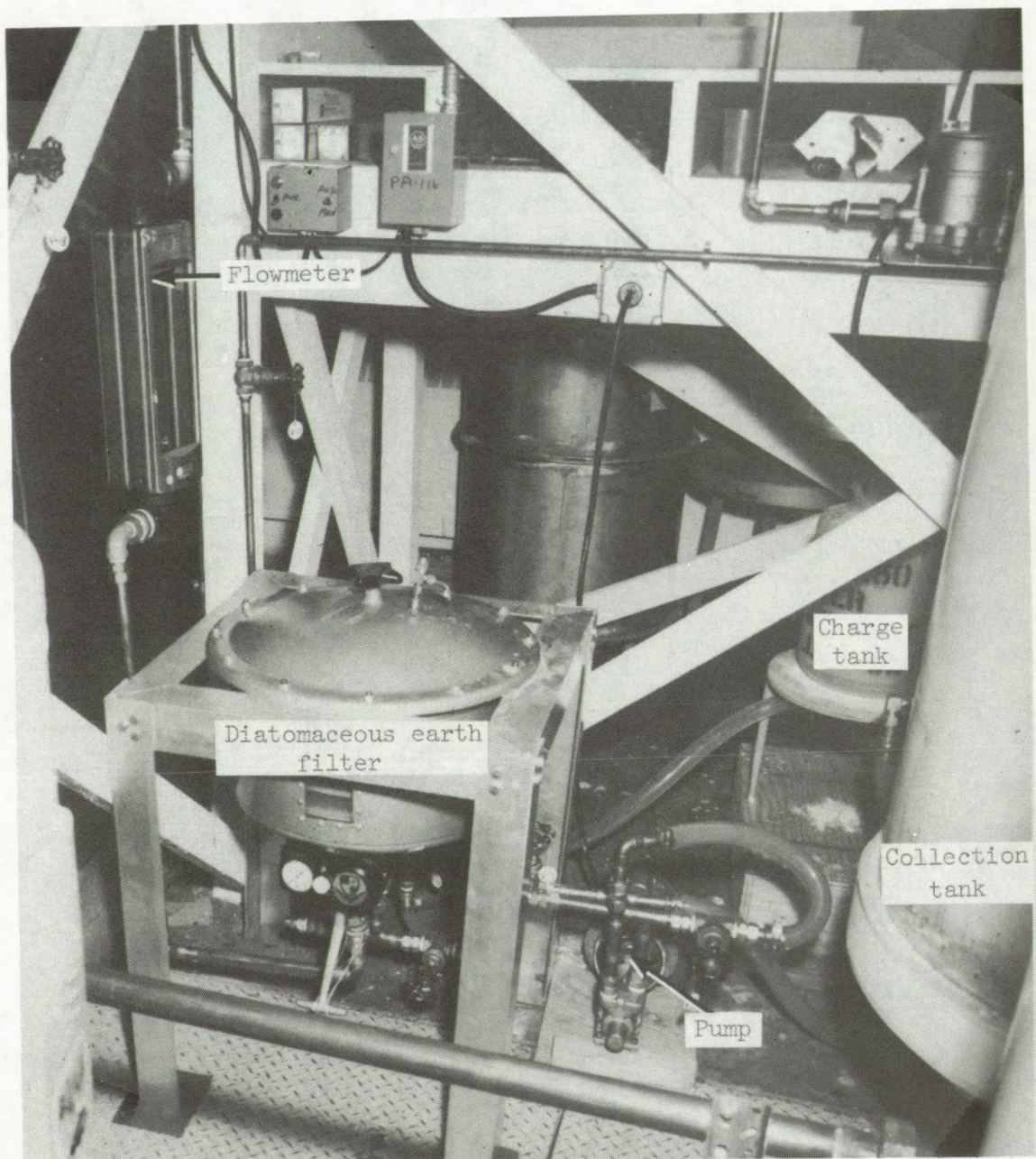


Figure 2.— Assembly and housing for diatomaceous earth filter screen discs.



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Figure 3.— Diatomaceous earth filter unit.

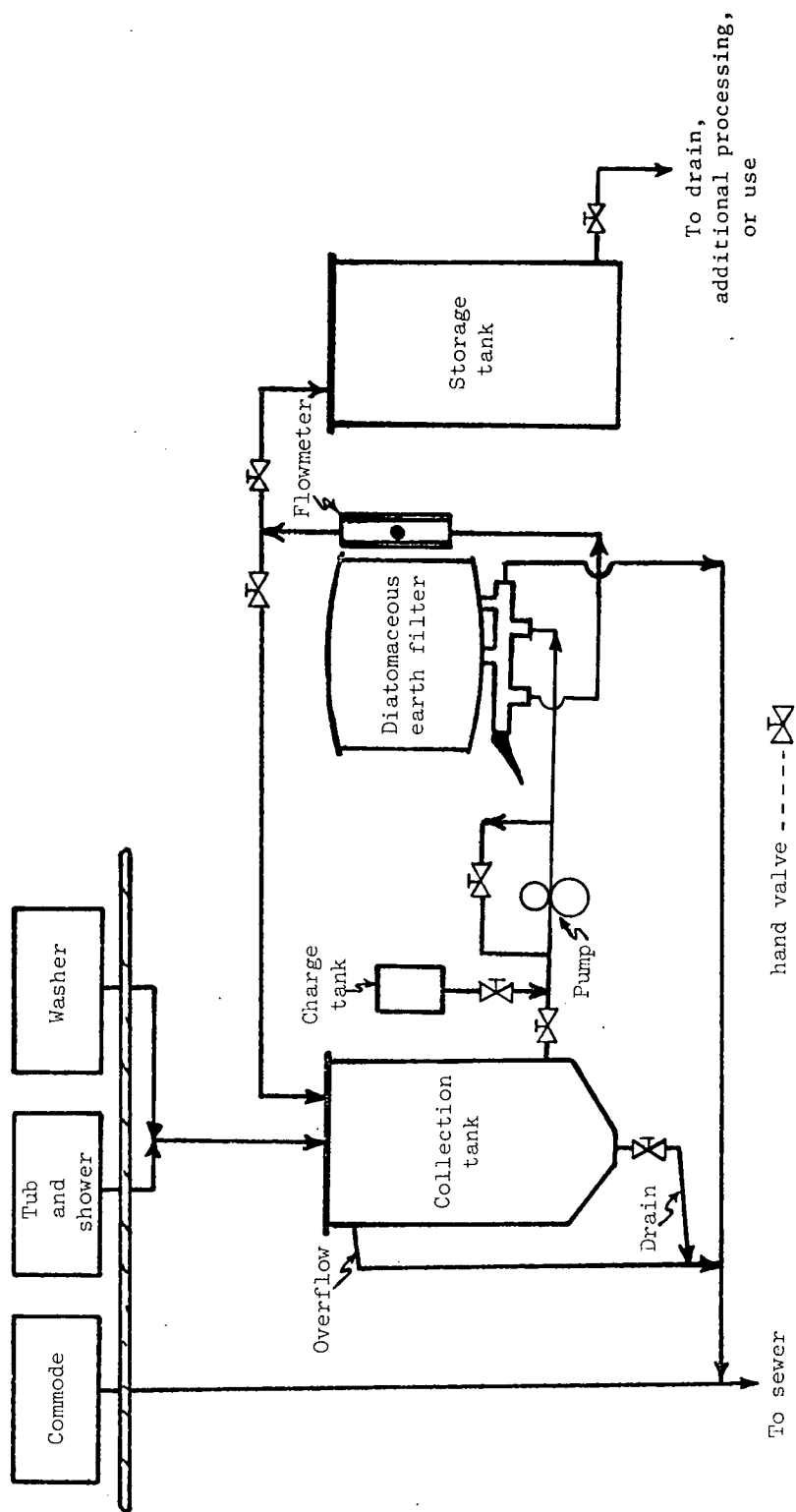


Figure 4.- Basic setup for collection, filtration, and storage of water.

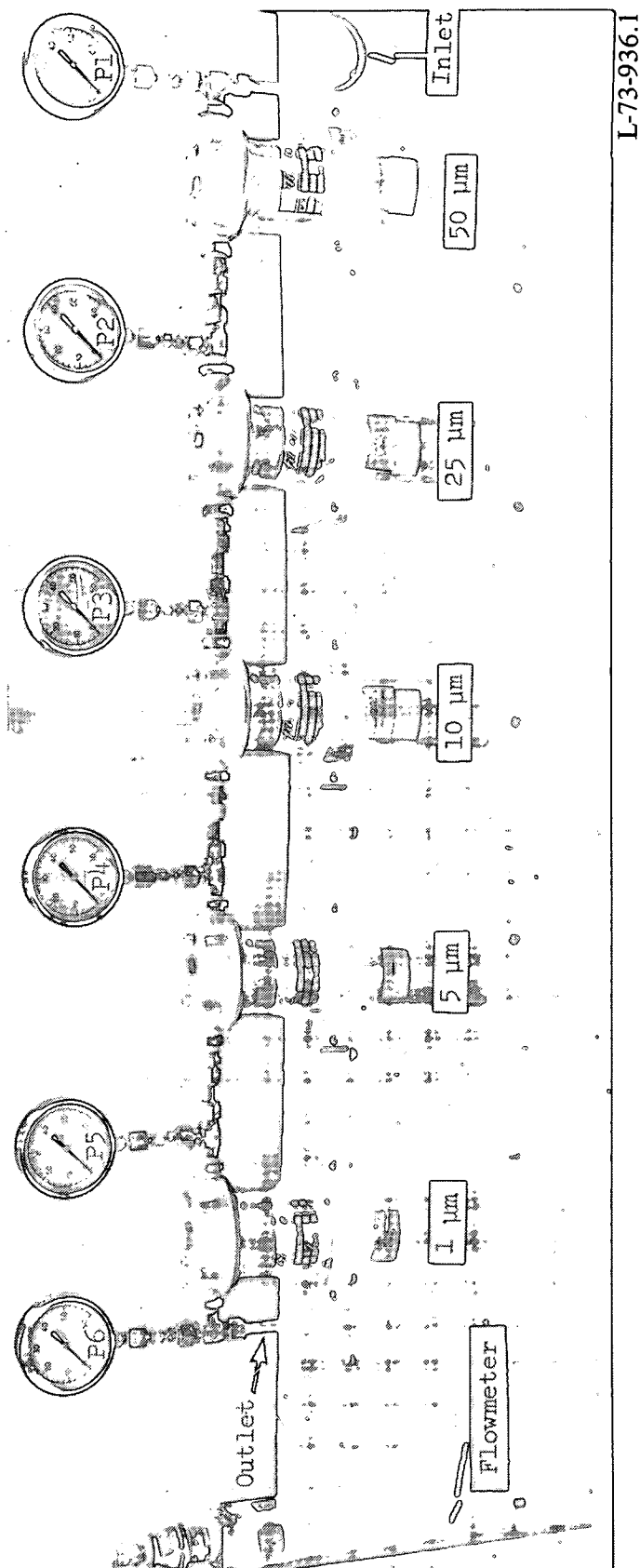


Figure 5.— Particulate filter arrangement.

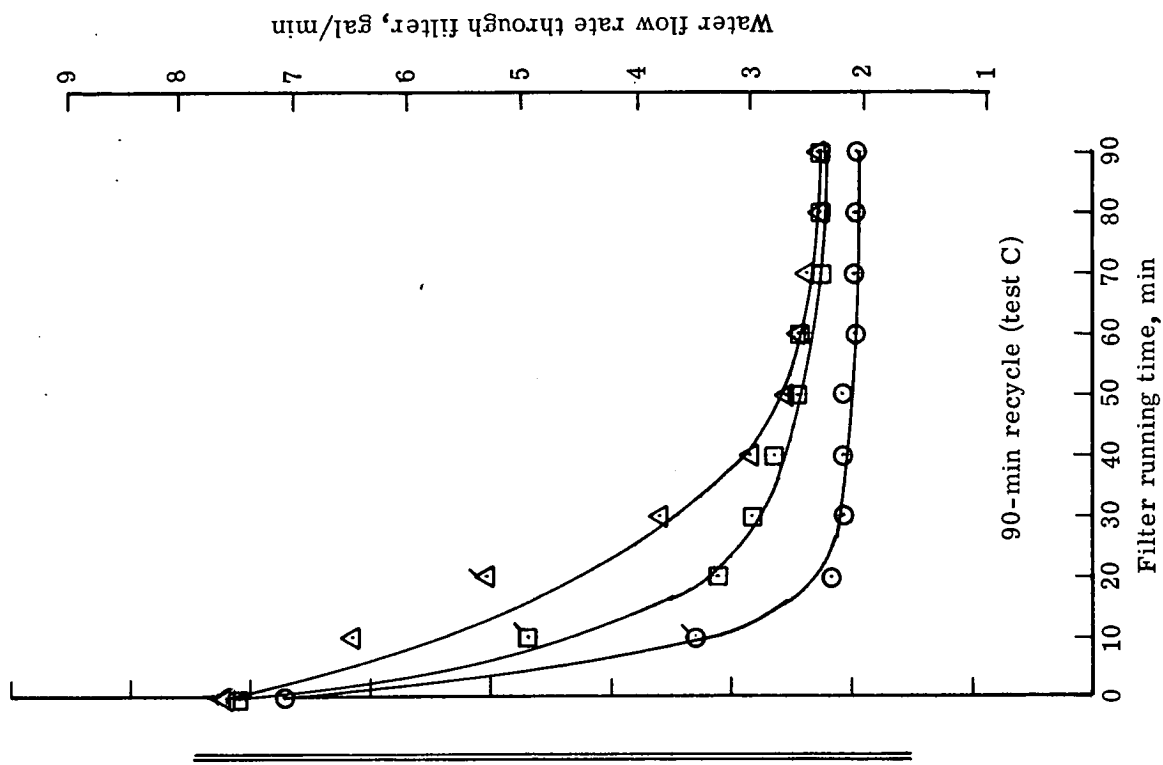
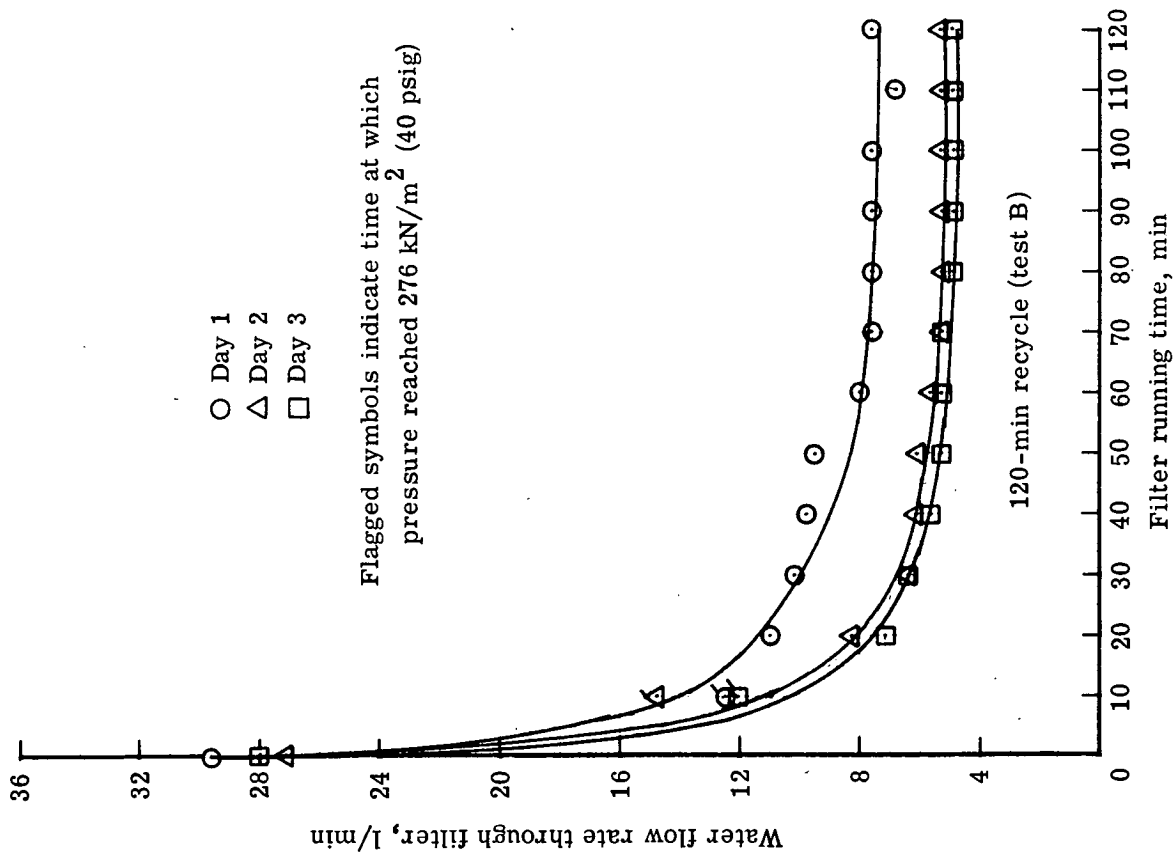


Figure 6.— Water flow rate during 120-min and 90-min recycle through a diatomaceous earth filter.

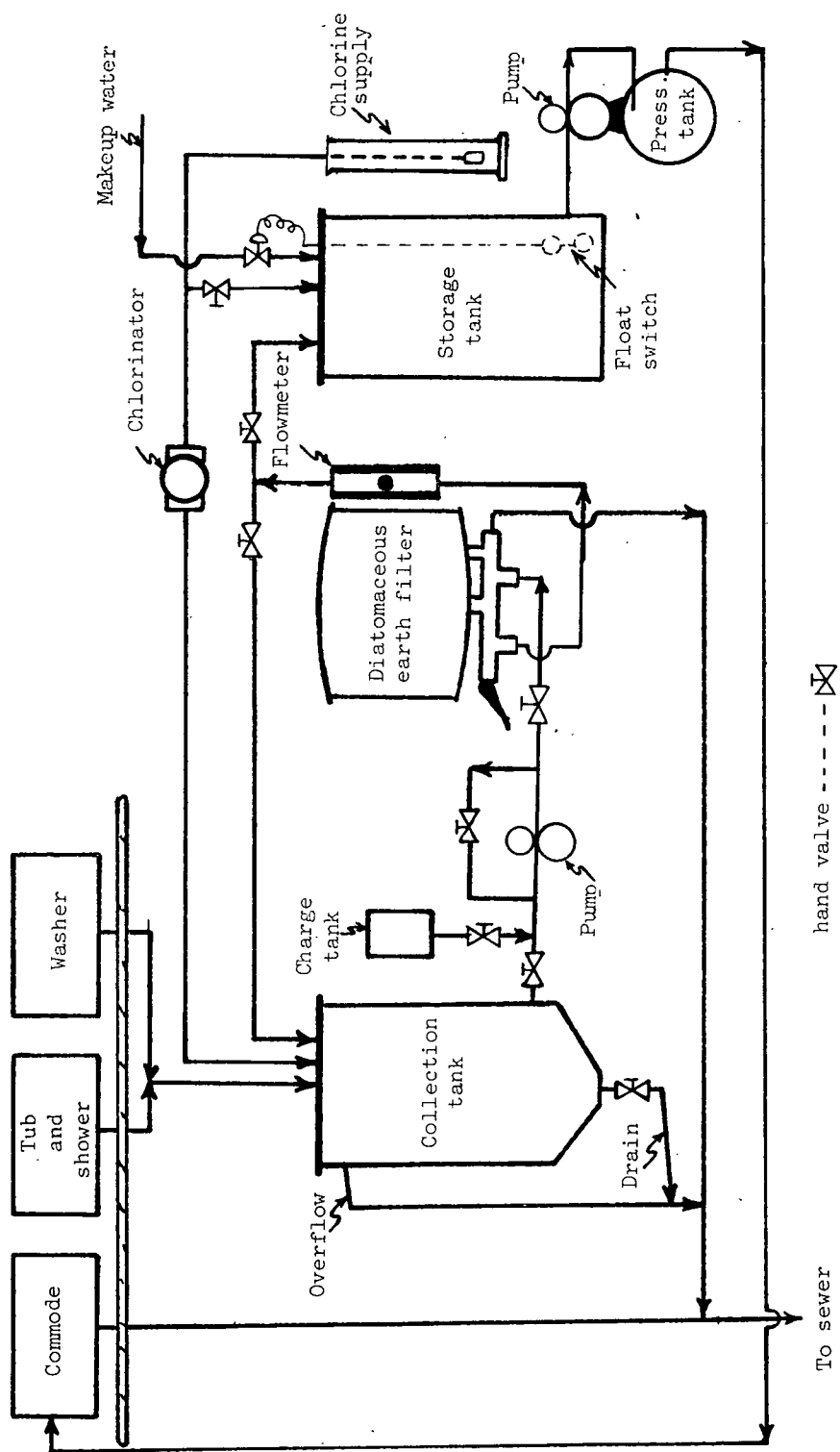
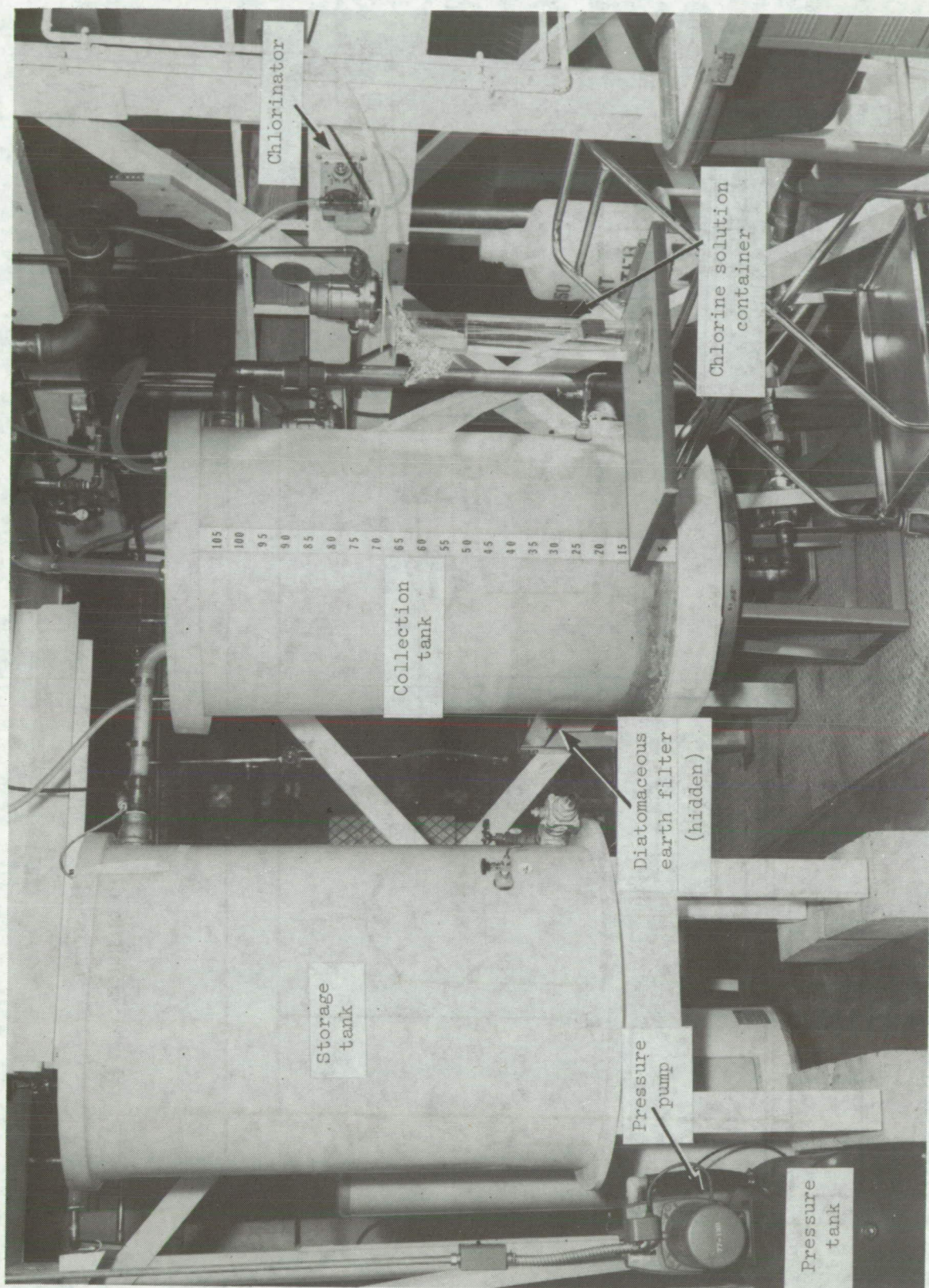


Figure 7.- Schematic of water reuse system using diatomaceous earth and chlorine.



L-72-7745.1

Figure 8.— Photograph of the water reuse system using diatomaceous earth and chlorine.

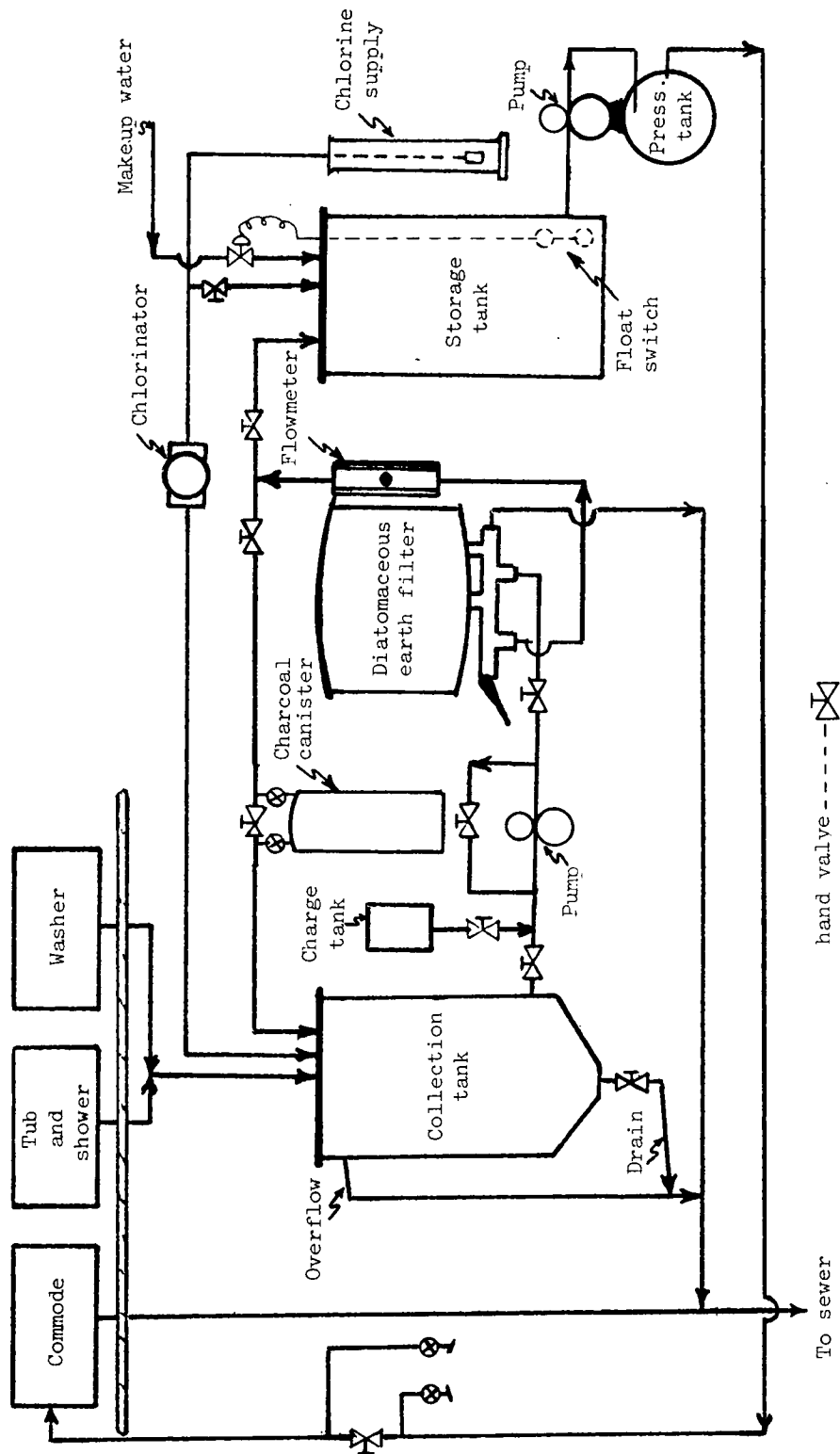


Figure 9.- Schematic of water reuse system using diatomaceous earth, charcoal, and chlorine
(charcoal canister in the diatomaceous earth filter recycle loop).



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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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